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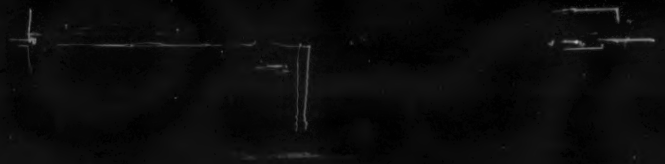

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LIMNOLOGICAL OBSERVATIONS ON SOME STREAMS OF THE NEW RIVER WATERSHED IN THE VICINITY OF MOUNTAIN LAKE, VIRGINIA

By Charles S. Shoup

A contribution from the Mountain Lake Biological Station of the University of Virginia, and Department of Biology, Vanderbilt University, Nashville, Tennessee

INTRODUCTION

In the summer of 1947, as a part of the work in limnology* at the Mountain Lake Biological Station, a survey of thermal and chemical characteristics of streams was undertaken preliminary to extensive investigations of the lake. Streams examined were those in the vicinity of Mountain Lake, on and adjacent to Salt Pond Mountain, Giles County. Some of the streams which were investigated are the same ones within Giles County previously examined with regard to fish distribution by Burton and Odum (1945), and may be identified on the U.S.G.S. (Virginia-West Virginia) Pearisburg Quadrangle map (Scale 1/62500), and on the U.S.G.S. (Virginia-West Virginia) Dublin Sheet (Scale 1/125000).

Salt Pond Mountain, on which Mountain Lake and the post office and hotel of the same name are located, rises to a height greater than 4000 ft. in northeastern Giles County. (Highest transit station is at Bald Knob, 4363 ft.) This represents a point on the divide between Atlantic and Mississippi drainage systems in Virginia, and the streams examined are all tributaries of New River, a stream originating in northwestern North Carolina which cuts across the parallel Appalachian ridges of Virginia to become the Kanawha of the Ohio drainage.

For investigation by the limnology group and because of accessibility, six streams of the above-mentioned drainage area were chosen. All stream-sampling localities lie within Giles County, with the exception of Station 3 at the headwaters of Sinking Creek, Craig County. (1) Sinking Creek, the most accessible stream examined, originates in a limestone spring of Craig County, and flows

* Personnel of the survey group: A. W. Burke (Va.); F. R. Derrick (N. C.); A. T. Hyde (Va.); C. T. Mann (Fla.); M. A. Miller (N. J.); J. Y. Peary (N. C.); J. B. Porter (Va.). C. S. Shoup, Party Leader. The author is indebted to these men for gathering data, their cooperation, and their close attention to details of operations.

westward between Sinking Creek Mountain and Gap Mountain and sinks underground in the cavernous limestone a few miles before entering New River. (2) Spruce Run Creek, a small lowland stream, originates also from a limey spring near Newport, Virginia, and flows in a narrow valley between Spruce Run Mountain and Gap Mountain, entering the New River near Goodwin's Ferry, Virginia. (3) Little Stony Creek, in contrast to the above, is a soft-water mountain stream originating on Salt Pond Mountain, from which it torrentially drops (3800 ft. to 1600 ft.) to the New River at Pembroke, Virginia. (4) Big Stony Creek, a typical mountain stream in its upper reaches, enters the lowland limestone near Kerns, and, gathering soluble buffers from limestone bedrock, quarries and cultivated lands, finally reaches the New River at Norcross not far below the bridge at Ripplemead. (5) Pond Drain, on top of Salt Pond Mountain, has all the characteristics of a small mountain brook, but in this instance it actually is, during most seasons, draining Mountain Lake, the high-altitude oligotrophic soft-water lake which lends its name to this section. (6) Hunter's Branch, also on top of Salt Pond Mountain, is a very small spring-fed brook whose chemical and thermal characteristics are typical of the highland streams of the region. Pond Drain and Hunter's Branch are tributaries of Little Stony Creek.

From an ecological viewpoint, these streams of mountain and lowland offer a favorable restricted locality for study because of their contrast in chemical and thermal characteristics and differences in biological productivity. In addition, the mountain and lowland streams reflect in the water chemistry the variation in solubilities of some constituents of their beds. In contrast, the higher streams flow over relatively insoluble sandstones and shales, while the lowland streams flow through more soluble dolomites and limestones with abundant materials sufficiently soluble to contribute a marked buffer action to the waters.

The stratigraphic situations which determine the relative amounts of soluble carbonate available as buffer in the bicarbonate buffer system operative in these streams, may be seen from the following geological descriptions (Butts, 1933) of the characteristic beds for each stream:

1. *Sinking Creek, Craig and Giles counties:*
   a. Upper: Cooper Ridge Dolomite (Ozarkian), a thick-bedded gray cherty dolomite of rather uniform character, with some interspersed sandstone.
   b. Lower: From above Maybrook downstream to New River: Stones River Dolomite of relatively pure limestone nature of the lower Ordovician (Canadian), a thick-bedded fossiliferous formation. These formations contribute varying amounts of calcium and magnesium carbonate to the stream.
2. *Spruce Run, Giles County:*
   This small stream, throughout its length, meanders in a narrow valley with opportunity of passage over bedrock from both the Copper Ridge Dolomite and the Beekmantown formations. Abundant soluble carbonates contribute to the high alkalinity of this lowland (1662–2400 ft.) stream.
3. *Little Stony Creek, Giles County:*
   In contrast with the above-mentioned streams, this one has its origin from

spring-fed mountain brooks at a high altitude on Salt Pond Mountain in the Clinch Sandstones (Silurian) of sediments and quartzites which make up the high ridges of the region. This is a hard white, grey, or reddish sandstone which contributes almost no buffer substances to the streams. In its lower portions, near Pembroke, this stream begins to pick up a higher bicarbonate alkalinity as it flows over thin alternating beds of broken dolomite of the Stones River and Beekmantown near New River.

4. *Big Stony Creek, Giles County:*
This stream, also originating in the Clinch Sandstone, is a typical mountain stream with characteristics of dissolved substances not unlike Little Stony Creek in its upper half. However, the lower half of this stream, from Foster Knob to New River at Norcross, traverses beds containing increasing quantities of the Beekmantown Dolomite with abundant commercial limestones. Drains and washes from adjacent quarries along the stream near its mouth add soluble carbonates.

5–6. *Pond Drain and Hunter's Branch, Giles County:*
These small streams are evidently confined to the Clinch Sandstone, and in their soft-water characters reflect the poor buffering action of this formation. Typically upland streams of variable flow, they filter through the broken sandstones and shales of this highland formation (3174–4000 ft.), with but small gain in buffer substances.

METHODS

The methods of stream examination and water analyses followed those previously reported upon for Tennessee (Shoup, 1940, 1944; Shoup, Peyton and Gentry, 1941), and were based upon those of Theroux, Eldridge and Mallmann (1936) for water analyses, and the New Hampshire biological survey report (Hoover et al., 1937) for most stream examination and grading. The main features of the methods are available in these publications, and special methods or references to them are cited below.

RESULTS

Stream Examination and Evaluation: The work of the survey group included not only field water analyses, but also some effort was made toward obtaining a general evaluation of the stream as a biologically-productive habitat, especially with reference to the presence of possible food and shelter for fishes. General field identification o bottom organisms and their comparative abundance, together with availability, yields some information on biological productivity. Bottom fauna were collected by the method suggested by Hazzard (1935) and extensively reviewed in the New Hampshire Report No. 2 (Hoover, et al., 1937). The procedure is accomplished by use of the Foerst square-foot sampler set up in at least three positions on characteristic stream bottom at a locality. Generally a sample is secured in the middle of a stream and in positions midway toward either bank. The apparatus is arranged with its bolting-cloth cone net down-stream, and then all stones are turned over and washed off from the square-

foot area marked off in front of the net, and all bottom sand and silt is stirred within the same square-foot area enclosed by the device. When the area has been thoroughly worked over, the contents swept into the net are dumped into a pan and thoroughly searched for organisms. Numbers of organisms and their total volume together constitute a food grade estimation. This is best shown by placing the specimens, freed of excess moisture, in a graduated centrifuge tube, and noting the total volume of material by displacement of water. In this instance, recognition must be made of numbers of organisms contributing to the total volume on the tripartite grading scale, viz:

Grade I (Exceptional richness). Volume greater than 2 cc. or 2 grams, with numbers greater than 50.

Grade II (Average). Volume from 1 to 2 cc. (1–2 grams), with more than 50 organisms.

Grade III (Poor). Volume less than 1 cc. (1 gram) and (or) not more than 50 organisms.

From the tabulations (Tables I–IV) it may be seen that the field observations and estimations favor the lowland streams in terms of both "wet food" volume and food grade. This is predominantly determined by numbers of organisms available rather than by distribution of species. It in no way detracts from the general consideration that warmer waters and more abundant microscopic forms with more rapid growing rates in the lowland streams contribute to the production of greater amounts of available food.

Temperature: Air and water temperatures were taken and recorded as °F. in the manner prescribed in the New Hampshire (1937) Report, and have previously been checked and recorded during the summer season by Burton and Odum (1945). Our temperature determinations ran somewhat higher than those indicated by Burton and Odum for Sinking Creek, but rather rapid flow during the season in Little Stony Creek and in Spruce Run accounted for slightly lower values for these localities. It would appear from our readings that water temperatures in mid-summer for the support of game fish are adequately low in these streams with the possible exception of the lower portions of Sinking Creek and Big Stony Creek. Presence of pools and shelter with adequate food and freedom from predators, including man, appear controlling factors on abundance of fishes in these streams.

Vegetation: Vegetation in the streams which might provide food and shelter, was found predominantly scant at most localities in keeping with the general characteristics of most mountainous streams. The term "scant" for vegetation has been described (Hoover, et al., 1937) as a situation where aquatic vegetation is seldom seen in the streams or the marginal waters, i.e., it does not exceed 10% in area coverage. The term "common" is applied to conditions where 10–50% of exposed rocks are with patches of vegetation or where marginal growth in the water occupies from 10–50% of the stream. Vegetation is extremely important in providing food for organisms which in turn serve as food for fry and fingerlings. It is likely that stream velocity and the type of bottom determines the abundance of vegetation. The mountainous streams examined, with variable flow over

sandy and gravelly bottoms where scouring action is possible, appear unlikely to support an adequate vegetation. The type of bottom found in most of the mountain streams, characteristically of fine to coarse gravel with rubble on sand, is detrimental to the establishment and maintenance of extensive vegetation.

Cover Evaluation: This is an estimation of available shelter and shade afforded a stream from each bank. Shade is a factor which influences temperature conditions in mid-summer, and in many localities an open stream which runs through pasture land and which is susceptible to warming by bright sunlight, particularly at pools, may be subjected to modification and control in this particular through provision of shore-line trees and shrubs. Cover or shade on the stream is estimated by judging how far the cover from each or either bank overhangs the stream. View of this is always taken from the middle of the stream, facing upstream, and values for left bank, right bank, and middle of the stream are assigned on the basis of a scale from 1 to 10, with the larger number indicating most adequate shade. Thus, a reading of $L_0R_0S_0$ would indicate minimum shade if the sun is directly overhead, while $L_{10}R_{10}S_{10}$ would designate a situation where adequate cover conditions permitted shading of the entire stream or pool at the locality with the sun directly above. It is therefore obvious that with but slight density of growth, gain in cover grade can sometimes be accomplished through marked overhang as well as spreading of tree limbs over the stream. Cover evaluation is high for the forested mountain areas mentioned in this report (See Tables I–IV), with clearings and low cover grades assigned to the lowland streams.

Bottom: In the case of these streams, the bottom is composed of broken bedrock, sand, and gravels or rubble of varying degrees of size. Hoover (1937), in the New Hampshire report, states that bottom is of great importance, not only with respect to food production and as a region for attachment of food organisms, but also as suitable fish spawning areas. The types of bottom are productive of food organisms in the following decreasing order: 1. Silt. 2. Small rubble. 3. Large rubble. 4. Coarse gravel. 5. Fine gravel. 6. Bedrock. 7. Sand. Bedrock does not always afford attachment surface suitable for organisms, and shifting sand displaces and smothers organisms. The rubble and coarse gravel of these Giles County streams doubtless have afforded cover and attachment areas. This is especially notable with respect to the numbers of insect larvae representing many Orders.

Chemical Characteristics: The water analyses were carried out at the sites of collection and at the time of collection, following the usual field methods suggested by Hazzard (1935), by Theroux, Eldridge and Mallmann (1936), and by the Standard Methods of the A.P.H.A. (1936), and as previously practiced (Shoup, 1940, 1943, 1944; Shoup, Peyton and Gentry, 1941). Free carbon dioxide (titratable), methyl orange alkalinity, phenolpthalein alkalinity, and dissolved oxygen are all expressed in terms of parts per million (p.p.m.). pH_1 represents the estimation of initial hydrogen-ion concentration, while pH_2 indicates the hydrogen-ion concentration of the sample following complete aeration into equilibrium with atmospheric carbon dioxide. The hydrogen-ion concentration,

estimated in terms of the pH scale, was checked by colorimetric methods, using the Taylor apparatus. In unpolluted natural waters such as these, most chemical factors are the amount of dissolved buffer substances, together with variable quantities of iron, silica, and anions such as chlorides, sulphates and nitrates. Field analyses are usually directed toward estimation of the buffer materials, or the constituents of the bicarbonate buffer system. Lamar and Whetstone (1945–1946), studying the chemical character of Virginia surface waters, have shown the influence of limestone in New River toward contribution to the alkali reserve of this stream, and Shoup (1944) has shown, through results from 371 samplings in Tennessee streams, that frequently the chemical character of an entire stream can be correlated with the solubility of buffers in its predominant bedrock formation. In general, streams draining from siliceous formations such as the Pre-Cambrian and Cambrian of East Tennessee or the Clinch Sandstone, will carry waters that are decidedly soft and are frequently mentioned as being the "free-stone" streams by natives of mountainous areas. The quantity of total buffer as bicarbonate in such streams will not be sufficient to offset change in pH by small amounts of dissolved carbon dioxide, so that characteristically such streams will have pH values on the acid side of neutrality because of predominance of carbonic acid over the bicarbonate present. The amount of carbon dioxide in the atmosphere in equilibrium with the water is quite enough to bring the pH to 6.0. Such conditions are characteristic of Little Stony Creek, Pond Drain, Hunter's Branch, and the upper part of Big Stony Creek where the Clinch Sandstone is the dominant surface formation and layers of dolomite are absent. In such areas, standing waters of bogs or swampy spots drop to very low pH values where both carbon dioxide and humic acids may be derived from vegetation. Near Station 5 alongside Little Stony Creek, and opposite the residence estate of White Pine Lodge may be found a bog embedded deep in thicket. This, at an altitude of 3174 ft. lies in a region free of limestone. Samples of the bog waters, taken from a mat of the vegetation, gave free carbon dioxide values of 63.0 p.p.m.; M.O. alkalinity of 8.0 p.p.m., and oxygen concentration of but 4.0 p.p.m. The initial samples had pH_1 values of 4.8, which on being aerated to eliminate volatile acid (CO_2), gave pH_2 of 5.2.

In the lower portions of these streams (Little Stony Creek and Big Stony Creek) and in those located in the dolomite formations (Spruce Run and Sinking Creek), soluble carbonate as both magnesium and calcium carbonates slowly changes the character of the waters to bring the pH values to 8.0 or above, with a rapid rise to more than 100 parts per million of total alkalinity as determined by titration. Excess carbonate, which is not held as bicarbonate (HCO_3) in the presence of carbon dioxide, is demonstrated by titration with phenolphthalein as indicator, and is referred to as the "phenolphthalein alkalinity" (P. Alk.), and this consequently means no free carbon dioxide is available in such waters excepting in pools. Spruce Run is the only stream of the group bearing these characteristics, combining a carbonate (CO_3) alkalinity with no free carbon dioxide and a quite high total alkalinity (122.0–135.0 p.p.m.) characteristic of a hard-water stream. Aquatic areas of this kind are typical lowland habitats of a good degree

of productivity in terms of bottom organisms and "wet food" volume. Headwaters of New River (Lamar and Whetstone, 1945–1946) are reported to be fairly

TABLE I

Limnological Data of Sinking Creek, Craig and Giles Counties, Va.

	STATION 1	STATION 2	STATION 3
Date	July 28, 1947	July 28, 1947	July 29, 1947
Air T., °F	75.5°	76.0°	83.0°
Water T., °F	70.5°	69.0°	80.0°
Water T., °C	21.3°	20.5°	27.4°
Hour	3:00 P.M.	4:10 P.M.	3:30 P.M.
Altitude	2200 Ft.	1800 Ft.	2300 Ft.
Av. Width	45 Ft.	25 Ft.	22 Ft.
Av. Depth	6 In.	2 Ft.	10 In.
Vol. Flow	20.0 Cu. Ft. Sec.	25.0 Cu. Ft. Sec.	6.0 Cu. Ft. Sec.
Velocity	1.1 Ft. per Sec.	0.5 Ft. per Sec.	0.2 Ft. per Sec.
Turbidity	Clear	Clear	Clear
pH_1	8.0	7.9	7.9
pH_2	8.1	8.1	8.1
Free CO_2	9.0 p.p.m.	8.0 p.p.m.	7.0 p.p.m.
M.O. alkalinity	110.0 p.p.m.	122.5 p.p.m.	118.0 p.p.m.
P. alkalinity	Zero	Zero	Zero
Oxygen	9.2 p.p.m.	9.2 p.p.m.	8.2 p.p.m.
Bottom	Sand. Fine gravel	Sand. Fine and coarse gravel	Sand. Fine gravel
Vegetation	Scant	Scant	Scant
Cover Grade	$L_8R_7S_0$	$L_8R_2S_0$	$L_6R_3S_0$
Food available:			
Annelida	−	−	+
Mollusca	+	+	+
Arachnida	+	+	+
Crustacea	+	+	+
Plecoptera	+	+	−
Ephemerida	+	+	+
Odonata	−	−	+
Hemiptera	−	+	−
Tricoptera	+	+	−
Diptera	−	+	+
Coleoptera	+	−	+
Neuroptera	−	−	−
Predators	−	−	−
Food volume	4.0 cc.	3.0 cc.	3.0 cc.
Food Grade	1	1	1

low in total alkalinity and gain in bicarbonate along the watercourse. Lamar and Whetstone (1945–1946) report M.O. alkalinity values for New River at Eggleston as 50–52 p.p.m. and pH 7.3–7.4. We have examined New River at the highway bridge 1 mile below Pearisburg, at a point where limestone washes from quarries enter the river, and have found the following characteristics:

New River: 1 mile below Pearisburg, Va.
July 31, 1947.
Air T°.: 89.0°F. Water T.°.: 80.0°F.
pH_1 = 8.0 pH_2 = 8.0
Methyl Orange Alk. = 50.0 p.p.m.
Phenolphthalein Alk. = 2.0 p.p.m.
Dissolved Oxygen = 8.0 p.p.m.

TABLE II

Limnological Data of Spruce Run Creek, Giles County, Va.

	STATION 6	STATION 7
Date	July 31, 1947	July 31, 1947
Air T., °F	81.0°	79.0°
Water T., °F	65.0°	67.0°
Water T., °C	18.3°	19.5°
Hour	9:50 A.M.	10:30 A.M.
Altitude	2027 Ft.	1662 Ft.
Av. Width	7.0 Ft.	12.0 Ft.
Av. Depth	3.0 In.	4.0 In.
Vol. Flow	3.0 Cu. Ft. Sec.	8.0 Cu. Ft. Sec.
Velocity	1.0 Ft. Sec.	1.0 Ft. Sec.
Turbidity	Clear	Clear
pH_1	7.9	8.2
pH_2	7.9	8.2
Free CO_2	Zero	Zero
M.O. alkalinity	122.0 p.p.m.	135.0 p.p.m.
P. alkalinity	3.7 p.p.m.	7.3 p.p.m.
Oxygen	8.8 p.p.m.	10.0 p.p.m.
Bottom	Sand. Fine gravel	Sand. Coarse gravel
Vegetation	Scant. Some algae	Scant. Sparse algae
Cover Grade	$L_3R_3S_0$	$L_3R_4S_0$
Food available:		
Annelida	−	−
Mollusca	+	+
Arachnida	−	−
Crustacea	+	+
Plecoptera	+	+
Ephemerida	+	+
Odonata	+	−
Hemiptera	−	−
Tricoptera	+	+
Diptera	−	−
Coleoptera	−	−
Neuroptera	−	−
Predators	Turtles. Snakes	Snakes abundant
Food volume	5.0 cc.	3.0 cc.
Food Grade	1	1

Natural waters of these qualities, which are unpolluted, will generally carry adequate quantities of dissolved oxygen in parts per million for support of fishes

and other fauna. Embody (1927) has indicated that brook trout waters should contain not less than 3 cc. of oxygen per liter, or 4.29 parts per million. Rocky mountainous streams, well-aerated through their fall over rubble and boulders

TABLE III

Limnological Data of Little Stony Creek, Giles County, Va.

	STATION 4	STATION 5	STATION 8
Date	July 30, 1947	July 30, 1947	July 31, 1947
Air T., °F	72.0°	81.0°	84.0°
Water T., °F	55.0°	61.0°	68.0°
Water T., °C	12.8°	16.0°	19.9°
Hour	10:30 A.M.	3:00 P.M.	11:30 A.M.
Altitude	3553 Ft.	3174 Ft.	1690 Ft.
Av. Width	6.0 Ft.	10.0 Ft.	15.0 Ft.
Av. Depth	3.0 In.	4.5 In.	6.0 In.
Vol. Flow	10.0 Cu. Ft. Sec.	20.0 Cu. Ft. Sec.	30.0 Cu. Ft. Sec.
Velocity	0.66 Ft. Sec.	0.83 Ft. Sec.	0.50 Ft. Sec.
Turbidity	Clear	Clear	Clear
pH_1	6.0	6.2	7.0
pH_2	6.0	6.1	7.2
Free CO_2	3.3 p.p.m.	2.0 p.p.m.	2.5 p.p.m.
M.O. alkalinity	4.0 p.p.m.	6.0 p.p.m.	17.0 p.p.m.
P. alkalinity	Zero	Zero	Zero
Oxygen	9.2 p.p.m.	8.04 p.p.m.	9.20 p.p.m.
Bottom	Sand. Fine gravel. Bedrock	Sand. Fine gravel. Boulders	Sand. Fine and coarse gravel
Vegetation	Common	Abundant	Scant
Cover Grade	$L_{10}R_{10}S_5$	$L_{10}R_{10}S_{10}$	$L_5R_7S_0$
Food available:			
Annelida	−	−	−
Mollusca	−	−	−
Arachnida	+	−	−
Crustacea	+	+	+
Plecoptera	+	+	+
Ephemerida	+	+	+
Odonata	−	−	−
Hemiptera	−	−	−
Tricoptera	+	+	+
Diptera	−	−	+
Coleoptera	−	−	+
Neuroptera	−	+	−
Predators	−	−	−
Food volume	−1.0 cc.	2.0 cc.	1.0 cc.
Food Grade	3	2	2

and through riffles, and free of pollution, may always be counted on as having a sufficient quantity of dissolved oxygen; an amount which is dependent upon the temperature of the waters. In some lowland streams, in warmer waters, and in pools, the oxygen saturation value may fall, but unless pollution is present, a

dangerously-low level for support of aquatic organisms is not likely to be attained. These streams of the east bank of New River all demonstrate an oxygen concentration in step with the water temperatures.

TABLE IV

Limnological Data of lower Big Stony Creek, Pond Drain, and Hunter's Branch, Giles County, Va.

	BIG STONY CREEK STATION 9	POND DRAIN STATION 10	HUNTER'S BRANCH STATION 11
Date	July 31, 1947	August 1, 1947	August 2, 1947
Air T., °F.	89.0°	75.0°	70.0°
Water T., °F.	75.0°	63.0°	55.0°
Water T., °C.	23.8°	17.2°	12.8°
Hour	3:20 P.M.	4:30 P.M.	11:20 A.M.
Altitude	2100 Ft.	3790 Ft.	3821 Ft.
Av. Width	10.0 Ft.	2.5 Ft.	0.5 Ft.
Av. Depth	6.0 In.	2.0 In.	1.0 In.
Vol. Flow	35.0 Cu. Ft. Sec.	1.0 Cu. Ft. Sec.	0.33 Cu. Ft. Sec.
Velocity	1.0 Ft. Sec.	1.0 Ft. Sec.	0.7 Ft. Sec.
Turbidity	Clear	Clear	Clear
pH_1	7.1	6.2	6.3
pH_2	7.2	6.4	6.4
Free CO_2	1.0 p.p.m.	7.0 p.p.m.	2.0 p.p.m.
M.O. alkalinity	23.0 p.p.m.	6.0 p.p.m.	5.0 p.p.m.
P. alkalinity	Zero	Zero	Zero
Oxygen	8.0 p.p.m.	9.20 p.p.m.	9.70 p.p.m.
Bottom	Sand. Fine and coarse gravel Boulders	Sand. Fine and coarse gravel.	Sand. Fine and coarse gravel
Vegetation	Scant	Scant	Scant. Some mosses
Cover Grade	$L_6R_4S_0$	$L_{10}R_{10}S_{10}$	$L_{10}R_{10}S_{10}$
Food available:			
Annelida	−	−	−
Mollusca	−	−	−
Arachnida	−	−	+
Crustacea	+	+	+
Plecoptera	+	−	+
Ephemerida	+	+	+
Odonata	−	−	−
Hemiptera	−	+	+
Tricoptera	+	+	+
Diptera	+	+	−
Coleoptera	−	−	−
Neuroptera	+	−	−
Predators	−	−	−
Food volume	2.0 cc.	0.2 cc.	3.0 cc.
Food Grade	2	3	1

The factors mentioned above as isolated features of the environment have relatively little influence on the productivity of food in a stream and the presence of large numbers or of many species of fishes. However, in the aggregate, tem-

peratures that are high enough to promote rather than retard growth, dissolved substances providing buffer action and mineral nutrition, an adequate oxygen supply, coupled with suitable cover and shelter, all do tend to support increase in numbers and species of food organisms. In absence of predators, the numbers and distribution of fishes should be beneficially influenced by the sum of these conditions. It is worthy of note that Burton and Odum (1945) found a rather wide distribution of fishes in both Sinking Creek and Spruce Run Creek and a somewhat more restricted distribution in terms of numbers of species in Little Stony Creek. If it is true, as Needham (1938) indicates, that food for game fishes is more abundant in the rather alkaline waters, our observed values for food volume and food grade would indicate production of more fish flesh per unit area in Sinking Creek and Spruce Run.

SUMMARY

1. Certain limnological characteristics of streams draining into the east bank of New River in the vicinity of Mountain Lake, Virginia, have been determined as a part of the work in limnology at the Mountain Lake Biological Station in the summer of 1947.

2. Field determinations of general water chemistry and productivity show these streams to be unpolluted and with chemical and thermal characteristics related to altitude and to the geological formations comprising the dominant bedrock.

3. In general, chemical and productivity features of Pond Drain, Hunter's Branch, Little Stony Creek, and the upper half of Big Stony Creek are all characteristic of mountain streams flowing through siliceous strata free of substances contributing to the alkali reserve. In contrast, within a short distance of the above, Sinking Creek and Spruce Run Creek show the characters of lowland alkaline streams of somewhat greater productivity potential in direct relation to the dominant dolomite strata comprising the bedrock of these streams.

4. The information obtained is a contribution toward knowledge of the biogeochemical relationships in fresh waters.

LITERATURE CITED

AMERICAN PUBLIC HEALTH ASSOCIATION. 1936. Standard Methods for the examination of water and sewage. 8th ed. pp. 1–309. N. Y.

BURTON, G. W., AND E. P. ODUM. 1945. The distribution of stream fish in the vicinity of Mountain Lake, Virginia. Ecology **26** (2): 182–194.

BUTTS, CHARLES. 1933. Geologic Map of the Appalachian Valley of Virginia with explanatory text. Vir. Geol. Survey Bull. No. 42, pp. 1–56, with map. University, Va.

EMBODY, G. E. 1927. An outline of stream study and the development of a stocking policy. Contrib. Aquicultural Lab., Cornell Univ., pp. 1–21. Ithaca, N. Y.

HAZZARD, A. S. 1935. Instructions for stream and lake survey work. U. S. Bur. Fisheries. (mimeo.) pp. 1–34. Washington.

HOOVER, E. E., ET AL. 1937. Biological Survey of the Androscoggin, Saco and Coastal Watersheds. Methods of stream and lake analysis. Survey Rept. No. 2, pp. 128–150. New Hampshire Fish and Game Dept., Concord.

LAMAR, W. L., AND G. W. WHETSTONE. 1947. Chemical character of surface waters of

Virginia. (1945–1946). Vir. Conservation Comm., Div. of Water Resources and Power, Bull. No. 8, pp. 1–46. Charlottesville, Va.

NEEDHAM, P. R. 1938. Trout Streams: Conditions that determine their productivity and suggestions for stream and lake management. pp. 1–233. Comstock Publ. Co., Ithaca, N. Y.

SHOUP, C. S. 1940. Biological and chemical characteristics of the drainage of the Big South Fork of the Cumberland River in Tennessee. Tenn. Div. of Game and Fish, Misc. Publ. No. 1, pp. 76–105. Nashville.

——— 1943. Distribution of fresh-water gastropods in relation to total alkalinity of streams. Nautilus **56** (4): 130–134.

——— 1944. Geochemical interpretation of water analyses from Tennessee streams. Trans. Amer. Fisheries Soc. **74**: 223–229. (Publ. 1947).

———, J. H. PEYTON, AND GLENN GENTRY. 1941. A limited biological survey of the Obey River and adjacent streams in Tennessee. Tenn. Div. of Game and Fish, Misc. Publ. No. 3, pp. 48–76. Nashville.

THEROUX, F. R., E. F. ELDRIDGE, AND W. LeR. MALLMANN. 1936. Laboratory manual for chemical and bacterial analysis of water and sewage. 2nd ed. pp. 1–228. N. Y.

A COMPARATIVE STUDY OF ZYGOTE GERMINATION IN THE SAPROLEGNIACEAE*

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Plates 1–6

The Saprolegniaceae have been of interest to botanists since 1823 when Nees von Esenbeck founded the genera *Saprolegnia* and *Achlya*. Scores of papers have now been written on the members of this family by men too numerous to mention here. These papers have covered morphology, taxonomy, cytology, and physiology of the species of this family so thoroughly that today it is perhaps the best known of the families of the Phycomycetes. Coker and Barnhart (1937) and Wolf (1944) give rather complete bibliographies of this group of fungi.

In spite of the great amount of work that has been done on these fungi, we are still lacking information on the complete life history of a number of the Saprolegniaceae. Most accounts of the species development of these forms stop at the fertilized egg which usually then undergoes a rest period before germination. The germinating oospore has been seen only in relatively few cases. This lack of information has probably been due to the varied length of rest of these species, and either to a supposed difficulty in germinating the eggs or a lack of interest in the procedure.

It was felt, therefore, that a worthwhile contribution could be made to this field by attempting to germinate the resting zygotes of several species, by performing several physiological experiments on the resting oospores, and by gathering together the literature on this subject which is spread over a period from 1860 to 1937.

HISTORICAL NOTES

In the literature of this family several terms are used synonymously. For example, the words oospore, egg, and zygote are used to connote the fertilized structures contained within the oogonium. While it is felt that the word zygote more definitely implies the fertilized egg, the other terms, through custom and long usage are retained in this paper.

In 1860, Anton de Bary published his description of a new genus, *Aphanomyces*, with several species. He observed the germination process in *A. stellatus* which he had maintained in a water culture for three months. De Bary described the gradual darkening of the oospore with its granular protoplasm and the putting forth from the oospore of a cylindrical germ tube which pushed through the

* This paper was condensed from a dissertation presented to the faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Botany.

oogonial wall to the outside. This tube branched immediately several times and the cytoplasm flowed into it until the oospore proper became empty.

Pringsheim (1873–1874) recorded the germination of the oospores of *S. ferax* by a short or long germ tube with a sporangium produced at the end, or a branched mycelium with several sporangia. In *A. polyandra* he showed the changes in the oospore from the mature egg to the short germ tube with a sporangium. Finally, he showed the short or long germ tube formation with probable zoosporangia in *A. racemosa*.

Sorokine (1876) practically repeated de Bary's work on *Aphanomyces*. He found that the oospores would germinate in the manner described by de Bary after three months of rest, or would germinate by producing a short germ tube which broke out of the oogonial wall and formed zoospores within 24 hours. Germination occurred only if the oospores remained in the light.

De Bary also mentioned zygote germination in his book on the fungi, mycetozoa, and bacteria. In a new species, *Aplanes Braunii*, he referred to the formation of a new thallus directly from the germ tube which developed from the germinating oospore.

While working on the karyology of *Saprolegnia*, Trow, in 1895, saw the germinating oospores of *S. Thureti*. He noted that the oospore wall became thin, the oil globule disappeared, and a germ tube was produced which formed a club-shaped sporangium.

In 1899, Trow, working on *Achlya americana* var. *cambrica*, gave a complete account of the germinating oospore. He pointed out that within six days after the oospore had reached maturity the inner wall began to dissolve, and the protoplasm increased in quantity. Meanwhile, the oil globule moved to center and was gradually decomposed and absorbed. The outer wall stretched, the inner wall completely disappeared, and the oospore increased in size with a vacuole in the center. After this, one or more germ tubes made their appearance, ceased growth, and produced small sporangia with four to ten zoospores. Trow also tried to hasten germination by subjecting the oospores to high temperature and ice but to no avail.

Klebs (1899) found that the oospores of *S. Thureti* (*S. mixta*) would either germinate by a short germ tube with an apical sporangium, or would form a mycelium directly on germination.

In 1911, Kasanowsky found the germinating oospores of *Aphanomyces laevis*. Germination had not been seen in this species prior to this time probably because the resting period of this form lasted about seven months. His findings, however, closely parallel those of de Bary for *A. stellatus*.

Not until 1918 was another record of oospore germination made. Weston, working on the development of *Thraustotheca clavata*, found that mature oospores placed in pure spring water maintained at 25° C. would germinate. Under these conditions the protoplasmic content increased, and the oil droplet became irregular and gradually disappeared. Meanwhile, the wall first swelled and was resorbed. It then became distended until it was comparatively thin. A hypha

was put out from the zygote which either formed a sporangium or grew into an extensive mycelium if enough nutrient were present.

In his book, "The Saprolegniaceae" (1923), Coker described the germinated eggs of *Achlya apiculata* var. *prolifera*. After 48 hours on agar the eggs sprouted to form long, branched threads.

The following year (1924), Coker and Couch, working with *Thraustotheca primoachlya*, found that the oospores germinated in the manner of those of *T. clavata* described by Weston. At room temperature the oospores would sprout in from ten days to two weeks.

Jones and Drechsler, in 1925, working on *Aphanomyces euteiches*, found that this form would germinate after a fifteen-day rest. Material from agar cultures was transferred to hanging drops and the oospores germinated either by mycelial development or by production of zoospores. The type of germination depended on the amount of nitritive material present. Mycelial growth occurred whenever particles of substratum were allowed to remain in the culture, and zoospore production when the material was allowed to soak first. The changes in the oospore prior to germ tube formation closely resemble those described by Weston for *T. clavata*.

While working on the problem of heterothallism in *Dictyuchus*, Couch (1926) was able to induce oospore germination after a resting period of six weeks to two months by placing the ripe oospores in boiled corn-grain juice or, as he later found, in boiled well water. The oospore changes before germination parallel those described above.

Patterson (1927) showed the beginning of the germ tube with nuclei and cytoplasm in *Achlya colorata*.

Schlösser (1929), working on several species of *Saprolegnia* whose normal resting periods were from three weeks to three months, was able to reduce this period somewhat by freezing the eggs for three days. He also found that germ tubes of individual zygotes do not always make their way through the top of the oogonium but mostly push through the oogone membrane at any convenient place.

In some unpublished observations on zygote germination in *Achlya orion* and *A. flagellata*, Couch (1933) found that the zygotes of *A. flagellata* were transformed into sporangia which opened by small tubes to the outside, allowing the eight or ten zoospores to escape. In *A. orion* he observed the changes prior to germination and found that these would germinate by rather long germ tubes with a sporangium formed at the end.

Latham, in 1935, refound Cornu's *Achlya recurva*. In this species the oospores mature in three days and are capable of immediate germination. Changes in the structure of the zygote prior to germ tube formation were not described. There was usually a single germ tube from each egg which grew out to a distance of 50–75 micra with a sporangium formed at the tip.

In 1937–1938 Schrader worked on the development of *T. clavata* and found that the oospores of this species have a rest period from twenty days to a much

longer time. He showed the two divisions of reduction division in the oospore, several germinational changes in the oospore, and the formation of the germ tube. He did not see the formation of sporangia, as they would not develop in his hanging drop preparations.

MATERIALS AND METHODS

Extensive collections of soil and water were made by the author in eastern and central North Carolina and northern and eastern South Carolina. The material was brought to the laboratory and baited with boiled split hemp seeds. Tap water mixed with charcoal, filtered, and autoclaved, was used for the soil cultures and rough isolation. Pure cultures of each form were made in the usual way on maltose-peptone agar #5. All final determinations of species were made from cultures grown on hemp seeds using distilled water which had been treated with charcoal, filtered, and autoclaved.

While awaiting the end of the resting period of the eggs, a pure culture of each form studied was placed in a 250-cc. Erlenmeyer flask with 150 cc. of charcoal-filtered distilled water. Several split hemp seeds served as food. The flasks were plugged with cotton and left on the laboratory table. This has proved to be an excellent way to keep cultures alive for several months and to avoid weekly washing and adding of food.

To observe the germinating eggs easily a small portion of the fungus mycelium was removed from the flask and placed in fresh charcoal distilled water on a slide. The water drop was spread out so the lens of the high objective would just avoid being wet. The whole slide was placed in a petri dish and additional water was added to prevent drying. The zygotes were easily seen under high dry power using this method, and the mycelium usually stayed in place on the slide when the stale water was removed and fresh added each morning by careful pipetting.

Germination studies were begun in an upstairs laboratory until a period of hot weather apparently stopped the germinating zygotes. The studies were then made in a basement where the temperature range during the entire study varied from 72° to 82° F. Temperatures above 85° F. seem to inhibit egg germination.

Additional techniques involving treatments other than those described above are written up under each experiment performed.

EGG GERMINATIONS

Aplanes treleaseanus (Humph.) Coker

Plate 1, figures 1–9

Aplanes treleaseanus was isolated from a soil collection and was seven weeks and one day old when placed in fresh water at 11:30 A.M. on June 25, 1947 (Fig. 1). The temperature during its development ranged from 76° to 81° F.

This specimen of *A. treleaseanus* differs from Coker's (1923) description in that the egg wall is not thick but relatively thin. However, a dark line of cytoplasm was noted immediately inside the egg wall, which might indicate that the eggs

had begun to germinate but ceased their development due to accumulation of staling products. This thin wall, then, might be due to this factor. Germination continued in fresh water and at 2:00 P.M., June 25, some of the cytoplasm had lightened somewhat but several dark areas had appeared in the periphery of the cytoplasm adjoining the oil droplets (Fig. 2). Eggs that are to disintegrate also had this same appearance rendering it difficult to determine whether an egg was to disintegrate or germinate. At 7:30 P.M. the oil droplets had become scattered throughout the cytoplasm and the dark area immediately beneath the wall had disappeared (Fig. 3). There was a slight increase in egg size and the wall was definitely much thinner. By 8:05 P.M. the cytoplasm had become less dense and a small vacuole had appeared (Fig. 4). At 9:30 P.M. the vacuole had increased in size and a small protrusion had formed on the side of the egg. A slight increase in egg size was noted (Fig. 5). By 1:00 A.M., June 26, the germ tube had elongated and passed to the outside of the oogonium through an oogonial pit. The cytoplasm was light in color with small glistening oil droplets scattered throughout (Fig. 6). The germ tube was observed at 9:00 A.M. and at 12:00 M. on June 26, but only an increase in length was noted. By 2:00 P.M. a cross wall had delimited the sporangium, which was filled with lightly colored, vacuolate cytoplasm (Fig. 7). This sporangium was not observed until 7:45 P.M. when nine spores had been formed (Fig. 8). By 9:30 A.M., June 27, each spore had begun to sprout.

The germ tube shown in detail in the drawings is not typical of most of those seen in the culture. Most of these were very long tubes as can be seen by the drawing made at 178 magnification (Fig. 9).

The stages in the germination of the eggs of *A. treleaseanus* resemble closely those shown and described by de Bary (1884) for *A. braunii* (*A. androgynus*), although he did not describe any detailed steps before germ tube appearance. In this species, de Bary pictures the germ tube as being short with a terminal sporangium. Short tubes do occur in *A. treleaseanus* but the germ tube usually is quite long before a sporangium is formed.

Germination began immediately after a portion of the mycelium was placed in fresh water and was completed within thirty-two hours.

Saprolegnia ferax (Gruith.) Thuret

Plate 1, figures 10–16

The culture of this form was five weeks and two days old when placed in fresh water on June 24, 1947, at 11:30 A.M. (Fig. 10).

The first stage in germination—a splitting up of the oil droplets and a darkening of the cytoplasm—was seen at 2:20 P.M., June 28, 1947 (Fig. 11). By 7:15 P.M. the same day, the oil particles had scattered throughout the cytoplasm and the egg wall had a scalloped appearance on the inner side. A definite increase in size was noted (Fig. 12). At 10:00 A.M., June 29, the egg wall had thinned considerably and a central vacuole had developed. A small germ tube had begun to protrude from the egg (Fig. 13). This tube had passed through

an oogonial pit to the outside by 4:00 P.M. (Fig. 14). After twenty-two hours (2:30 P.M., June 30) the germ tube had grown in length somewhat and the egg cytoplasm had passed out into the tube (Fig. 15). Another egg in the oogonium, meanwhile, had germinated in the manner described above. The germ tubes were rather short and thick and cross walls formed in the germ tubes delimiting the sporangia near their exit from the oogonial pits. Seven spores were liberated from the sporangium of the first germinating egg at 8:30 P.M., June 30, 1947 and the second germ tube sporangium later released five spores.

Germination began three days and twenty-two hours after the mycelium was placed in fresh water and was completed within two days and seven hours after its inception.

Saprolegnia delica Coker

Plate 2, figure 4

Saprolegnia delica was eight weeks and two days old when it was placed in fresh water at 3:00 P.M., July 7, 1947. During its development the temperature ranged from 72° to 77° F. The first evidence of germination was noticed seven days and one hour after the mycelium was placed in fresh water and was completed within three days and twelve hours after it began. The stages of germination closely resemble those described for *S. ferax*. The drawing shows an oogonium in which four eggs have germinated.

Saprolegnia megasperma Coker

Plate 2, figures 1–2

The culture of this form was twelve weeks and two days old when placed in fresh water. The germination of this large species had been attempted six other times before this but with no success.

Early germination stages resemble those of other members of the genus *Saprolegnia* with no variation from the usual pattern. A large number of germinated zygotes were seen. In the majority of cases, the germ tube ceased growth very shortly and produced a single short sporangium (Fig. 1). In other cases a very long germ tube developed with a small sporangium at the apex. Two instances of a germ tube forming several functional sporangia were observed. One of these is shown in Figure 2. In all cases, the spores which were liberated behaved as in *Saprolegnia*.

Germination began thirty hours after the mycelium was placed in fresh water. The process was completed two days and twenty-two hours after it began.

Saprolegnia diclina Humphrey

Plate 2, figures 5–6

This species, collected at Chapel Hill, N. C., was two months and five days old when placed in fresh water at 10:00 A.M. on October 15, 1947.

The first evidence of germination—a breaking up of the oil globules—was seen

at 2:20 P.M. on October 16. The germination of this species so closely resembles *S. ferax* and the other species of *Saprolegnia* that one is referred to those species for the details of the process.

By 8:35 A.M., October 18, a long germ tube had been formed by the oospore and an apical sporangium was being formed (Fig. 2). This discharged about eight spores at 11:50 A.M. the same day (Fig. 6). Meanwhile, a second egg in the same oogonium had germinated but a very short germ tube was formed with a rather clavate sporangium. The more usual type is the former one and these were fairly abundant in my culture (Fig. 5).

The first stage in germination was seen twenty-eight hours after the mycelium was placed in fresh water and was completed within an additional forty-five hours.

Saprolegnia litoralis Coker

Plate 2, figure 3

Saprolegnia litoralis had remained in the flask for eleven weeks and one day before being placed in fresh water at 2:30 P.M., July 24, 1947.

The beginning of development was not observed until 9:05 A.M. on August 2. Its early development resembled both *S. ferax* and *S. delica* and the early stages described for those forms are applicable to this species.

The germ tubes were quite large and usually fairly short. They passed to the outside through the large and conspicuous oogonial pits. Cross walls formed either long-cylindrical or slightly buibous sporangia. Examples of both are shown—the two types occurring from germinating eggs in the same oogonium (Fig. 3). The sporangia emptied their spores in the manner typical of *Saprolegnia*.

The first sign of germination was seen eight days and nineteen hours after a portion of the mycelium was placed in fresh water. The process was concluded within two days and five hours after it began.

Isoachlya unispora Coker and Couch

Plate 2, figures 7–11; Plate 3, figure 1

Frequent attempts to germinate the zygotes of this species were unsuccessful until October 1, 1947, when the culture was four months and two days old. The use of the term zygote is debatable here as no antheridia are formed, but it is used merely for convenience.

Previous unsuccessful attempts to germinate this species, *I. intermedia*, and *I. itoana* had included the use of various nutrient decoctions, agar, alkaline and acid solutions, and growth in the incubator and cold room.

A portion of the mycelium was placed in fresh water at 10:20 A.M., October 1, 1947, when the culture was four months and two days old (Plate 2, fig. 7). The first indication of germination was seen at 8:15 A.M., October 3, when the central cytoplasm had darkened and the oil globules appeared to be breaking up into smaller particles (Fig. 8). By 12:20 P.M. the oil layers as such had dis

appeared and glistening particles appeared throughout the darkened cytoplasm. The inner zygote wall was scalloped and ragged in appearance (Fig. 9). During the next twelve hours, the zygote wall had become uniformly thin, the cytoplasm had become less granular, and a central vacuole had formed (Fig. 10).

The egg put out a germ tube which passed through the single conspicuous pit to the outside. This had attained a length equal to the zygote width by 10:50 A.M., October 5 (Fig. 11). It continued to grow during the remainder of the day and most of October 6 and produced sparse branches. A sporangium was formed on the apical end, seven spores were cut out, and these were discharged at 3:10 P.M., October 6, swimming away as in *Saprolegnia*. Several other sporangia were formed in a cymose arrangement as seen in Plate 3, figure 1.

In my culture, a large number of zygotes germinated. Eighty per cent germinated in the manner described above. The remainder formed a long, branched, intertwining, hyphal system.

Forty-six hours after the mycelium was placed in fresh water the first sign of germination was seen. The germination process required three days and seven hours.

Isoachlya intermedia (Coker and Harv.) Coker

Plate 3, figure 2

The culture of this form was five months and three weeks old when the zygotes germinated. Many previous attempts to germinate this species had failed. (See *I. unispora*.) The zygotes would germinate only when they were placed in a weak corn-grain solution (Couch, 1926). The zygotes could not be germinated in fresh water.

The details of the germination process resemble those described for *I. unispora*. In the zygote followed through its development, only a much branched, long mycelium was formed. In other cases, the germinating zygote produces not only a long branched mycelium but also zoosporangia. This last type may be seen in Figure 2.

Germination began twenty-three hours after the culture was placed in corn-grain juice. The process was complete about thirty-one hours after it began.

Isoachlya itoana Nagai

Isoachlya itoana Nagai was collected by Mr. Arthur Kelman of State College, Raleigh, N. C., who identified it and kindly gave me a culture.

Several attempts to germinate the zygotes of this species had resulted in failure. Germination was obtained, however, by placing a culture five months and one week old in corn-grain juice. (See *I. intermedia*.) A second culture was placed in fresh water but failed to germinate.

Details of the germination process are like those figured and described for *I. unispora* and *I. intermedia*. The germ tube in this species finally formed a much branched mycelium with a single sporangium. Only five zygotes have been seen to germinate and all formed a mycelium and a single zoosporangium.

Germination began twenty-six hours after the mycelium was placed in the

corn-grain decoction. Spores were liberated two days and fourteen hours after germination.

Achlya colorata Pringsheim

Plate 3, figures 3–8; Plate 4, figure 1

My culture of this fungus was five weeks and four days old when placed in fresh water on July 7, 1947, at 2:30 P.M. (Plate 3, fig. 3).

One egg had begun germinating by 8:20 A.M., July 8. The cytoplasm had darkened noticeably beneath the wall and the two layers of oil droplets appeared to be splitting up into smaller fragments. These gradually invaded the clear space immediately beneath the wall. Several dark areas were noticed in the central cytoplasm (Fig. 4). By 2:20 P.M. the scalloped egg wall had become thinner and a slight increase in size of the egg was evident (Fig. 5). At 8:00 P.M. the wall had reached its final thinness and a central vacuole had developed with a slight lightening of the cytoplasm (Fig. 6). A small germ tube had put out from the egg by 9:30 A.M., July 9 (Fig. 7). The only other change noticed during the remainder of the day and July 10 and 11 was an increase in length of the germ tube (Fig. 8). At 4:30 P.M., July 11, the germ tube had attained its maximum length and a cross wall had formed delimiting the sporangium. Spore initials were being formed as the drawing was made (Plate 4, fig. 1). Approximately twenty-two spores were formed and were liberated by 9:15 A.M., July 12.

No mention was made above of the germ tube's passing to the outside of the oogonium. *Achlya colorata* has rather thick oogonial walls with short blunt outgrowths. The germ tube described above apparently passed through the oogonial wall at a thin place in the wall caused by the antheridial tube. A slight constriction of the tube as it passed through this thin spot may be noted on Plate 4, figure 1. However, in several cases, the germ tube in its passage to the outside actually split the oogonial wall. Several examples of this have been seen.

Patterson (1927) had seen the germinating eggs of this form, but there has been no general account of the germination process in this species up to now.

The first evidence of germination was seen twenty hours after beginning the experiment and germination was completed in four days.

Achlya racemosa Hildebrand

Plate 4, figure 2

This species, which had been isolated from a soil collection, was ten weeks and six days old when placed in fresh water at 9:45 A.M., July 27, 1947.

In its development this species parallels closely its related form *A. colorata*. The developing germ tube, however, emerges through a pit caused by an antheridial tube and produces a sporangium typical of *Achlya* (Fig. 2). Numerous discharged sporangia were to be found in the culture with the number of discharged zoospores averaging about eleven.

Forty-eight hours elapsed before the first indication of germination was seen and the process was concluded three days and ten hours after it began.

Achlya flagellata Coker

Plate 4, figures 3–10

My culture of this form was four weeks old when it was placed in pure fresh water at 9:30 A.M. on June 1, 1947. Several germinating eggs were noted on June 4, so a single oogonium was then kept under observation until germination was complete (Fig. 3).

The first evidence of germination was noted at 9:15 A.M., June 5, when the egg had increased very slightly in size and the protoplasm had become darker. The oil droplet moved from the periphery toward the center and became completely surrounded by cytoplasm. Except in the area adjacent to the former position of the oil drop, a general thinning of the wall occurred (Fig. 4). By 2:05 P.M. the same day, a further increase in size of the egg was noted. The oil drop had moved to an upper sector and the surrounding egg wall had become thin (Fig. 5). At 7:50 P.M. there was no further increase in size of the egg but the oil drop had become small, and the wall very thin. There was a general darkening of the cytoplasm due to increased granulation (Fig. 6). The oil drop completely disappeared by 8:15 P.M. and a central vacuole had become evident (Fig. 7).

A short germ tube grew from the egg during the approximate five hours between 8:15 P.M., June 5, and 1:05 A.M., June 6. The end of this tube was touching a pit on the oogonial wall. The granular cytoplasm became lighter and the egg had increased slightly in size (Fig. 8). By 3:10 A.M., June 6, the germ tube had grown through the pit to the outside. A definite constriction was noted as the tube passed through the pit and a swelling occurred immediately after opening to the outside. The cytoplasm was now quite pale and a vacuole could be seen in the egg and the germ tube (Fig. 9). At 5:10 A.M. this tube had grown to a distance of 138 micra and a cross wall had been formed cutting off a sporangium (Fig. 10). The old egg was by now completely empty. By 9:30 A.M. spores had emerged and were clustered at the mouth of the sporangium. These were later observed to germinate and swim away.

The germination process began four days and ten hours after the mycelium was placed in fresh water. Germination was completed twenty-four hours after it began.

Achlya proliferoides Coker

The culture of this form was eight weeks and six days old when placed in fresh water. It was kept under observation one week before any signs of germination were noted. Its development was exactly the same as that described for *A. flagellata*, which shows a further very close relationship between these two species. This experiment has since been repeated twice with the hope that some dissimilarity between the two species might be found which would provide a really distinctive key character. Development took thirty-one hours from the first encircling of the oil drop by the cytoplasm to the emptying of the seven spores from the germ tube sporangium.

Achlya caroliniana Coker

Plate 4, figure 11

This specimen of *A. caroliniana* was two months and five days old when it was placed in fresh water at 4:00 P.M., July 7, 1947. Its development closely resembled that of the other species of *Achlya* with eccentric eggs. In my culture germination was effected by the formation of a sporangium at the apical end of the germ tube (Fig. 11). Numerous eggs in the culture germinated and the average zoospore count of ten sporangia was seven.

The first evidence of germination was seen twenty hours after the beginning of the experiment and was completed within forty-eight hours after it began.

Achlya americana Humphrey

Plate 4, figures 12–13

The identification of this form is still in doubt as it somewhat resembles *A. conspicua* Coker. However, we will call it *A. americana* until a positive identification can be made. Several attempts had been made to germinate this species, which had been in a resting condition since May 5, 1947, but none was successful until a portion of the mycelium was placed in fresh water at 10:15 A.M. on September 29, 1947.

The development of the eccentric eggs closely parallels that described for *A. flagellata*. Germination is effected by the production of a germ tube with an apical sporangium (Fig. 12). However, it was not unusual for the growth of the tube to continue another twenty-four hours before a sporangium was produced. This growth resulted in a sparsely branched mycelium with an apical sporangium which, in general, was smaller than the one produced by a shorter tube (Fig. 13).

On the whole my observations made on this species follow those made by Trow (1899) on *A. americana* var. *cambrica*, although there seems to be a great divergence in the length of resting periods of these two forms.

Germination began twenty-four hours after the mycelium was placed in fresh water. It was complete three days and seven hours after it began.

Achlya glomerata Coker

Plate 5, figures 1–2

This form was three weeks and five days old when placed in fresh water at 4:15 P.M., October 3, 1947.

The first stage in germination—the surrounding of the oil globule by the cytoplasm—was seen at 11:15 A.M. on October 4. The changes in the zygote during the germination process were like those described for other species of *Achlya* with eccentric eggs. By 2:25 P.M., October 6, 1947, a germ tube about nine times the width of the zygote had formed and an apical sporangium had been cut off (Fig. 2). The sporangium passed through the usual changes prior to spore release and five spores were liberated at 3:45 P.M. the same afternoon.

Achlya flagellata Coker

Plate 4, figures 3–10

My culture of this form was four weeks old when it was placed in pure fresh water at 9:30 A.M. on June 1, 1947. Several germinating eggs were noted on June 4, so a single oogonium was then kept under observation until germination was complete (Fig. 3).

The first evidence of germination was noted at 9:15 A.M., June 5, when the egg had increased very slightly in size and the protoplasm had become darker. The oil droplet moved from the periphery toward the center and became completely surrounded by cytoplasm. Except in the area adjacent to the former position of the oil drop, a general thinning of the wall occurred (Fig. 4). By 2:05 P.M. the same day, a further increase in size of the egg was noted. The oil drop had moved to an upper sector and the surrounding egg wall had become thin (Fig. 5). At 7:50 P.M. there was no further increase in size of the egg but the oil drop had become small, and the wall very thin. There was a general darkening of the cytoplasm due to increased granulation (Fig. 6). The oil drop completely disappeared by 8:15 P.M. and a central vacuole had become evident (Fig. 7).

A short germ tube grew from the egg during the approximate five hours between 8:15 P.M., June 5, and 1:05 A.M., June 6. The end of this tube was touching a pit on the oogonial wall. The granular cytoplasm became lighter and the egg had increased slightly in size (Fig. 8). By 3:10 A.M., June 6, the germ tube had grown through the pit to the outside. A definite constriction was noted as the tube passed through the pit and a swelling occurred immediately after opening to the outside. The cytoplasm was now quite pale and a vacuole could be seen in the egg and the germ tube (Fig. 9). At 5:10 A.M. this tube had grown to a distance of 138 micra and a cross wall had been formed cutting off a sporangium (Fig. 10). The old egg was by now completely empty. By 9:30 A.M. spores had emerged and were clustered at the mouth of the sporangium. These were later observed to germinate and swim away.

The germination process began four days and ten hours after the mycelium was placed in fresh water. Germination was completed twenty-four hours after it began.

Achlya proliferoides Coker

The culture of this form was eight weeks and six days old when placed in fresh water. It was kept under observation one week before any signs of germination were noted. Its development was exactly the same as that described for *A. flagellata*, which shows a further very close relationship between these two species. This experiment has since been repeated twice with the hope that some dissimilarity between the two species might be found which would provide a really distinctive key character. Development took thirty-one hours from the first encircling of the oil drop by the cytoplasm to the emptying of the seven spores from the germ tube sporangium.

Achlya caroliniana Coker

Plate 4, figure 11

This specimen of *A. caroliniana* was two months and five days old when it was placed in fresh water at 4:00 P.M., July 7, 1947. Its development closely resembled that of the other species of *Achlya* with eccentric eggs. In my culture germination was effected by the formation of a sporangium at the apical end of the germ tube (Fig. 11). Numerous eggs in the culture germinated and the average zoospore count of ten sporangia was seven.

The first evidence of germination was seen twenty hours after the beginning of the experiment and was completed within forty-eight hours after it began.

Achlya americana Humphrey

Plate 4, figures 12–13

The identification of this form is still in doubt as it somewhat resembles *A. conspicua* Coker. However, we will call it *A. americana* until a positive identification can be made. Several attempts had been made to germinate this species, which had been in a resting condition since May 5, 1947, but none was successful until a portion of the mycelium was placed in fresh water at 10:15 A.M. on September 29, 1947.

The development of the eccentric eggs closely parallels that described for *A. flagellata*. Germination is effected by the production of a germ tube with an apical sporangium (Fig. 12). However, it was not unusual for the growth of the tube to continue another twenty-four hours before a sporangium was produced. This growth resulted in a sparsely branched mycelium with an apical sporangium which, in general, was smaller than the one produced by a shorter tube (Fig. 13).

On the whole my observations made on this species follow those made by Trow (1899) on *A. americana* var. *cambrica*, although there seems to be a great divergence in the length of resting periods of these two forms.

Germination began twenty-four hours after the mycelium was placed in fresh water. It was complete three days and seven hours after it began.

Achlya glomerata Coker

Plate 5, figures 1–2

This form was three weeks and five days old when placed in fresh water at 4:15 P.M., October 3, 1947.

The first stage in germination—the surrounding of the oil globule by the cytoplasm—was seen at 11:15 A.M. on October 4. The changes in the zygote during the germination process were like those described for other species of *Achlya* with eccentric eggs. By 2:25 P.M., October 6, 1947, a germ tube about nine times the width of the zygote had formed and an apical sporangium had been cut off (Fig. 2). The sporangium passed through the usual changes prior to spore release and five spores were liberated at 3:45 P.M. the same afternoon.

However, only about one half of the zygotes in my culture germinated in the manner described above. Very frequently, the zygote produces a long branched mycelium which twines in and out among the other eggs in the culture. A single zygote was followed through in its development and it produced the mycelium shown in Figure 1. About ninety per cent of the zygotes on the slide germinated during this experiment.

The first evidence of germination was seen nineteen hours after the mycelium was placed in fresh water and required two days and four hours for completion.

Achlya crenulata Ziegler

Plate 5, figure 3

This form (Ziegler, 1948) was six weeks and three days old when placed in fresh water at 9:00 A.M., June 16, 1947.

The germination process is typical of those described for other species of *Achlya* with eccentric eggs. The egg that was followed through its development unfortunately did not show the typical condition in germ tube formation. As shown in Figure 3, it produced a germ tube which grew out some distance and then formed a branch near its base which also grew out. The cytoplasm of the original germ tube flowed into this secondary branch and formed a sporangium.

However, many eggs germinated in the culture and all, with this one exception, formed a single germ tube with an apical sporangium. The zoospores from ten different sporangia were counted and the average was nine.

Germination probably began at about the twenty-sixth hour after the mycelium was placed in fresh water and was completed within an additional two days and six hours.

Achlya recurva Cornu

Plate 5, figure 4

The oogonia of this species were two weeks and two days old when they were placed in fresh water.

The development of the germinating eggs of this species closely parallels those eccentric eggs such as *A. flagellata*, *A. proliferoides*, and *A. caroliniana* already described. The only difference we have been able to see is that the oil drop usually does not disintegrate entirely before germ tube formation but may persist—at least a small part of it—until the germ tube has attained some length.

Latham (1935) observed the germinating eggs of this species but did not follow the process through in detail. This species is very closely related to *Thraustotheca primoachlya* and resembles it not only in external features but also in the fact that its eggs germinate readily. It is distinguished from *T. primoachlya* by having the type of sporangia characteristic of *Achlya*, and longer protuberances. *T. primoachlya*, of course, produces sporangia of the *Thraustotheca* type. See Plate 5, figure 4, and Plate 6, figure 1, for comparison.

Achlya recurva began to germinate twelve hours after it was placed in fresh water and the process was completed in thirty-one hours after it began.

Achlya apiculata de Bary

Plate 5, figure 5

The culture of this form was nine weeks and five days old when it was placed in fresh water. Development resembles that described for *A. colorata*, *S. ferax*, and *I. unispora*. Germination is usually effected by the production of sporangia. However, the eggs do occasionally produce long mycelial threads which usually do not branch (Fig. 5).

Coker (1923) had germinated the eggs of *A. apiculata* var. *prolifera* on agar. On a solid medium, long unbranched threads were formed. However, as we have shown here, eggs germinated in water predominantly form sporangia, with an occasional thread formation.

Germination began five days and twenty-three hours after the mycelium was placed in fresh water. It was completed after an additional four days and four hours.

Protoachlya hypogyna Shanor and Con.
Achlya hypogyna Coker and Pem.

Plate 5, figures 6–8

The nomenclature of this species is confused and misleading. In 1908 Coker and Pemberton (Bot. Gaz. **45**: 194) described *Achlya hypogyna* from Chapel Hill. In 1923 Coker (The Saprolegniaceae, p. 90) established the genus *Protoachlya* and transferred to it his old species *A. paradoxa* but not *A. hypogyna*. In 1942 Shanor and Conover described a species from Illinois as *Protoachlya hypogyna* and attempted, on the basis of what was then known of *Achlya hypogyna*, to show that the two were different. At that time Dr. Coker agreed to the distinction. However, later culture work has proved beyond a doubt that the Chapel Hill species belongs to the genus *Protoachlya* and is the same as the plant from Illinois, but the combination *Protoachlya hypogyna* (Coker and Pem). Shanor and Con. cannot be used as the latter authors were not transferring the older species.

Miss Josephine Stewart collected *A. hypogyna* in Chapel Hill again in 1946 and it has been maintained in culture since that time. As Figures 6–8 show, the eggs on germinating produce long unbranched germ tubes with apical sporangia. A total of nine sporangia were seen and all discharged their spores in the manner typical of *Protoachlya*.

Germination began twenty hours after the mycelium was placed in fresh water. It was completed within seventy-two hours after it began.

Aphanomyces laevis de Bary

Plate 5, figure 11

Several previous attempts to germinate the eggs of this species resulted in failure but germination was seen after the culture was five months and two weeks old. The development of the eggs recall that of *A. flagellata* and other species of *Achlya* with eccentric eggs. Three types of germination were found. In the first, the germ tube formed a long, unbranched hypha. In another type, which

was by far the most common seen in my preparations, the original germ tube branched after leaving the oogonium and finally produced a small, branched mycelium. A low power view of this condition may be seen in Figure 11. The last type was seen only twice. It consisted essentially of the mycelium plus a single sporangium.

As recorded under "Historical Notes", several other workers have seen the germinating eggs of this genus, among them, de Bary, Sorokine, Kasanowsky, and Jones and Drechsler.

Twenty-three hours after being placed in fresh water the first sign of germination was seen. The process was completed in about three days and twenty-one hours.

Thraustotheca clavata (de Bary) Humphrey

Plate 5, figures 9–10

The culture of this form was eleven weeks and three days old when a portion of the mycelium was placed in fresh water.

My observations on the germination of this specimen closely follow Weston's (1918) descriptions and drawings in his work on this species. However, as only pure water was used in my cultures, no extensive mycelial formation occurred. Weston's Figure 59 shows what he describes as an oil globule becoming irregular and disappearing. This closely resembles the disintegrating eggs which are quite common throughout a culture. The gradual absorption of the oil drop is very easily seen in fresh water mounts and does not differ from the process described in *A. flagellata*. Sporangial formation is shown in Figures 9 and 10.

Germination began four days and four hours after the mycelium was placed in fresh water. The process was completed five days after it began.

Thraustotheca primoachlya Coker and Couch

Plate 6, figure 1

This species and *Dictyuchus missouriensis* were sent to me by Dr. Leland Shanor of the University of Illinois. The culture was four and one half weeks old when placed in fresh water. The stages of egg germination in this species closely resemble those already described for *T. clavata*, and *A. flagellata*. Coker and Couch (1924) have already worked out the details of egg germination for this species. Germination in this form readily occurs after a rest period of at least ten days. I was not able to find any eggs in which the entire tube and egg space became the sporangium.

Twenty-five hours after the mycelium was placed in fresh water the first stage in germination was noticed. An additional twenty-six hours was needed for completing the process.

Dictyuchus missouriensis Couch

Plate 6, figures 2–7

The culture of this form was fourteen weeks and one day old when it was placed in fresh water at 9:45 A.M., October 6, 1947 (Fig. 2). The first visible

evidence of germination was noticed at 12:15 P.M., October 8, when the diminishing oil globule was surrounded by granular cytoplasm (Fig. 3).

The germination stages for this species are like those described and drawn by Couch (1926) in his work on heterothallism in this genus. The egg walls become irregular and scalloped, the oil droplet is broken up, and a germ tube is produced. Figures 3 to 5 show these stages.

The germ tubes of this species are usually from ten to thirteen times longer than the oogonial width (Fig. 7). Those seen by Couch appear to be much shorter. From six to eleven spores are produced in the sporangia.

The first evidence of germination was noted two days and three hours after the mycelium was placed in fresh water. The germination process required two days and twenty-three hours.

Geolegnia inflata Coker and Harvey

Plate 6, figures 17–23

This species and the following one were collected by Mr. William Pendergrass in soil collections from Florence, S. C.

The mycelium was six weeks and two days old when placed in fresh water at 9:30 A.M., September 29, 1947 (Fig. 17). Due to the extreme smallness of the species, the first stages in germination were missed but by 1:45 P.M., October 1, the oil globule had come to occupy a more central position and had decreased to about one half its original size (Fig. 18). By 4:35 P.M. a further decrease in size of the oil drop was noted and the wall appeared scalloped on the inner side. There had been a gradual darkening of the cytoplasm during the interval (Fig. 19).

At 9:00 A.M., October 2, the germinating zygote had increased in size and the wall had become thin. A central vacuole had developed (Fig. 20). A germ tube began to protrude from the zygote at 11:10 A.M., October 2, and by 12:10 P.M., October 3, this germ tube had attained the length shown in Figure 21.

Geolegnia inflata will germinate readily after a rest period when it is placed in fresh water. The germ tubes form a primary mycelium without branches and I have never seen spores formed in this species. The lengths of two of these germ tubes are shown in Figures 22 and 23.

The germination of this species closely resembles those described for the eccentric *Achlya* species although its size somewhat restricts careful observation.

The germination process began forty-eight hours after the mycelium was placed in fresh water. It was completed within two days and three hours after it began.

Brevilegnia linearis Coker and Braxton

Plate 6, figures 8–16

My culture of this form was three weeks old when it was placed in fresh water at 10:50 A.M., July 17, 1947 (Fig. 8).

Details of the germination process were extremely difficult to see. The very small oogonia, each with a single egg, are the same size as the abundant zoospores

and the eggs are frequently to be seen without the oogonial wall and intermingled with the zoospores.

The first stage in germination was not noticed until 12:10 P.M., July 19, when the cytoplasm became slightly darker and surrounded the fat globule (Fig. 9). By 8:25 P.M. the same day, the wall had begun to thin and the oil droplet had decreased noticeably in size (Fig. 10). On July 20 at 11:25 A.M., the cytoplasm had become very granular, the oil drop had further decreased in size, and a slight enlargement of the egg was noticed (Fig. 11). By 7:50 P.M. the same day, a vacuole had developed in the egg and the oil globule was much smaller (Fig. 12).

At 8:15 A.M., July 21, a small germ tube had arisen and protruded through the oogonial wall, probably through a thin place in the wall caused by the antheridial tube (Fig. 13). By 9:25 A.M., July 22, this germ tube had attained a length of about ten times the diameter of the oogonium but did not branch (Figs. 14–15).

In eight germinating eggs observed in my cultures, three germinated in the manner described above with a long unbranched hypha. Five of the eight eggs had long branching germ tubes such as is shown in Figure 16. No sporangia were observed.

Germination began twenty-five hours after the mycelium was placed in fresh water and required an additional two days and twenty hours for completion.

TESTS FOR FATTY MATERIALS

In the eggs of the Saprolegniaceae, numerous small droplets or one large droplet of a substance which has been called oil or fatty reserve are present. These droplets give the eggs their characteristic appearance; *e.g.*, a centric egg has one or two layers of small oil droplets completely surrounding the cytoplasm; a subcentric egg has two or more layers on one side and one layer on the other; an eccentric egg has a single large drop completely outside the protoplasm. In order to determine the exact composition of this material, several tests have been performed. These tests have certainly been made by other workers in this field but a search of the available literature has failed to disclose any mention of them in the articles which I have examined. They are:

1. Sudan III. Used as a presumptive test. Stains all fatty substances deep orange yellow.

2. Sudan IV (Scarlach R). Stains fats orange red.

3. Osmic acid. Exposure to osmic acid 1/2 % solution for several hours usually completely blackens all fats.

4. Nile blue sulphate. Although this is a controversial stain in that it is doubtful whether a stain can differentiate between such components as fatty acids, mixtures of fats, and true fats, we have included it here simply for a record. With this stain, fatty acids become pink, mixtures of fats turn violet, and fats become blue.

5. Saponification. 20% NH_4OH and saturated aqueous KOH. When material is treated with equal parts of the above mixture and then observed under polarized light, sphaerocrystals should become evident if fat is present.

6. Polarization. Fats under polarized light should have an isotropic appearance if no fat-like substances are present.

7. Solubilities. Fats are soluble in ether, petrol ether, chloroform, acetone, benzene, carbon disulphide, carbon tetrachloride, phenol, xylol and other substances. Several of these solvents were applied to the fungus material.

The results were as follows:

1. Sudan III

A. flagellata—large oil drop stained dark orange.
A. apiculata—oil droplets stained bright orange.
S. ferax—oil droplets stained bright orange.

2. Sudan IV

A. flagellata—large oil drop stained orange yellow.
A. apiculata—oil droplets stained orange yellow.
S. ferax—oil droplets stained orange yellow.

3. Osmic acid. Exposed to fumes of 1/2% for two hours. Oil in all cases turned black.

4. Nile blue sulphate. Oil in all three cases stained blue with no indication of other colors.

5. Saponification. Under treatment described above, numerous sphaerocrystals were observed in all three species.

6. Polarization. All oil droplets were isotrophic.

7. Solubilities. Solubility tests were made using xylol, ether, acetone, and carbon tetrachloride. In all cases, the fatty material was either soluble or partly soluble.

The results indicate that the material present in the three forms studied is true fat and that no fat-like substances are present. The slight divergence of the results in the solubility tests is due, perhaps, to the presence of some additional substances which are not fatty.

EFFECTS OF pH ON GERMINATION

Various factors such as light, temperature, amount of food, and pH of the medium influence the germination process in the eggs of the Saprolegniaceae. An experiment to determine the role of pH on the eggs of several species is described here. Five species representing several genera and both eccentric and centric eggs were used. These were *Protoachlya hypogyna* (centric eggs), *Saprolegnia ferax* (centric eggs), *Saprolegnia delica* (centric eggs), *Achlya recurva* (eccentric eggs), and *Thraustotheca primoachlya* (eccentric eggs).

The various pH solutions were made by using different amounts of a 0.1 molar solution of KH_2PO_4 and K_2HPO_4 and were checked on an electric potentiometer. The cultures were mounted in the usual manner but the pH solution was used instead of fresh water. After seventy-two hours, the results were studied. This experiment has been repeated several times with comparable results being received each time.

Several conclusions were reached after a study of the data obtained. In all cases a low pH such as 4.9 and 5.9 tended to inhibit the germination of the zygotes, as very few would germinate. If they germinated at this pH range,

they deviated from their usual germination pattern in fresh water. In most cases where they germinated by germ tubes with apical sporangia, a low pH caused the eggs to produce long, branched germ tubes with no formation of sporangia. Except in the case of *Achyla recurva*, zygotes would not germinate in a pH of 7.9. No zygotes germinated in a solution of 8.8 The zygotes underwent the same development in a pH of 6.9 as they do in fresh water.

EFFECT OF LIGHT ON GERMINATION

Sorokine, in 1876, following the work of Anton de Bary, was able to germinate the eggs of *Aphanomyces*. He discovered, among other facts, that the eggs would germinate only if they remained in the light. In reviewing the literature, this seems to be the only reference to this phenomenon. In order to corroborate this fact, three species which I have found to germinate readily were chosen. They were *Protoachlya hypogyna*, *Achlya recurva* and *Thraustotheca primoachlya*.

These forms were placed on slides in the manner described under "Materials and Methods." Two cultures were made of each species. One culture of each was immediately placed in the dark in the desk and the other placed on the laboratory table. Thermometers showed that the temperature on the table and in the desk were the same. (The temperature was not kept constant but the variations were the same.) Water was changed on each culture every morning. The cultures were opened and examined at the end of seventy-two hours and results recorded. The culture kept in the dark was then left in the light for an additional seventy-two-hour period to see if the zygotes would germinate.

The results can easily be summarized. For the three species used in this experiment, light is necessary for germination. This experiment has been repeated seven times and the results each time were comparable to each other. Occasionally, several zygotes have germinated in the dark but their total average would scarcely be one-sixth per ten fields.

After the above had been demonstrated, several trials to test egg germinations under different wave lengths of light were made. However, the results were inconclusive as too many variable factors were present.

A COMPARISON OF THE TYPES OF RESTING BODY GERMINATION IN THE OOMYCETES

This thesis is chiefly concerned with the germination processes exhibited by the members of one family, the Saprolegniaceae. The germination of the resting bodies of other families and orders of the Phycomycetes has been seen from time to time but the references to these phenomena are scattered throughout the various texts and sundry papers.

We have therefore endeavored to bring together the forms in which germination has been seen and attempt to fit them into different groups or patterns of germination. Finally, we shall try to make several general remarks concerning germination in this entire class.

As will be seen in the following pages, the germination patterns of the resting

bodies of the Phycomycetes are highly varied and these will be discussed by taking up each order separately.

Chytridiales

Sparrow (1943) lists and describes many species of Chytrids. The resting bodies of a great many of these forms have never been seen. In only 24 species of Chytrids has the germinating process been witnessed.

The resting spore is formed sexually in but 5 of the 26 species which have been seen to germinate. These are: *Polyphagus euglenae*, *Rhizophidium Couchii*, *R. ovatum*, *Micromyces longispinosus*, *Pringsheimiella dioica*, *Synchytrium endobioticum*, and possibly *Diplophlyctis intestina*.

Due to the incompleteness of the literature, it would be impossible to make any general conclusions regarding resting spore germination in the whole order. However, the forms in which germination has been seen do fall into several distinct groups. These are:

1. Those in which a small apical pore is formed with the resting body functioning as a pro-sporangium. The sporangium formed may or may not have an operculum.

Rhizidium mycophilum, *Polyphagus euglenae*, *Rhizophydium Couchii*, *Entophlyctis vaucheriae*, *Endochytrium* sp., *Diplophlyctis intestina*, *Megachytrium westonii*, *Chytrium olla*, *C. schenkii*, *C. lagenaria*, *Rhizidiopsis emmanuelensis*, *Phlyctochytrium synchytrii*, *Micromyces longispinosus*, *Blyttiomyces spinulosus*, *Rhizosiphon crassum*, *Septochytrium variabile*.

2. Those in which the resting body functions as a sporangium forming a discharge tube.

Diplophlyctis intestina, *Rhizophydium ovatum*, *R. transversum*, *R. messanense*, *Olpidium luxurians*, *Pringsheimiella dioica*, *Rozella allomycis*, *R. achlyae*, *Cladochytrium replicatum*.

3. This group includes only one form: *Zygochytrium aurantiacum*. In this group the exospore wall cracks and the endospore wall elongates into a thick tube.

Sparrow (1943) points out "... Sorokin's genus has been almost universally rejected by monographers and mycologists in general. This rejection has been strengthened by the lack of further observations on the organism. Sorokin's descriptions and figures of the development and reproductive processes are unusually clear and distinct, and there seems no reason for doubting them. Since it is now apparent that the chytrids have evolved a variety of types of sexual reproduction it is not surprising to find a form having a method like that observed in another group of Phycomycetes." Sparrow is referring, of course, to the similarities between the sexual reproduction of this form and that, say, of *Rhizopus*. However, the germination of this form indicates a relationship with the oomycetes.

The changes in the resting body prior to germination are described by Karling (1939). These are:

1. Small germ tube pore develops in the thick wall.

2. Meanwhile the refractive central globule changes shape.
3. Protoplasm begins to ooze through the pore.
4. Globule becomes invaded on the periphery adjacent to the pore.
5. Sporangium develops in the outside; main globule now broken up.
6. Spores cut out.

It will be noted that several of the steps are reminiscent of those found in the Saprolegniaceae. For example, the breaking up of the oil globule, the passage of cytoplasm to the outside before the oil is completely disintegrated as in *A. recurva*, and the cutting out of the spores in the sporangium on the exterior of the original resting spore.

Blastocladiales

The resting body of the Blastocladiales is a thick-walled, punctate structure which is a sporangium in function and which liberates zoospores on discharge. It is comparable to the resting body of the Chytrids but not to the resting bodies of the higher forms.

As stated before, in this Order, germination of the resting spore always produces zoospores. Some other criterion must be found, therefore, in order to attempt any classification of the species in which germination has been seen. This criterion might possibly be the manner in which the resting spore wall cracks open. It is unfortunate, though, that this event has not been sufficiently described in some of the literature. If this characteristic can be used, the species fall into the following types:

1. Those in which the resting spore germinates by the cracking of the exospore wall into several irregular pieces after which the hyaline inner part sends out one or more papillae. (A key character in the diagnosis of *Blastocladiella*—see Couch and Whiffen, 1942.)

Blastocladiella variabilis, B. stübenii, B. simplex, B. asperosperma, B. laevisperma, B. microcystogena.

2. Those in which the resting spore wall splits open along a pre-formed longitudinal line.

Blastocladia pringsheimii (not actually stated but drawings show this to be highly probable), *Coelomomyces* sp.

3. That one in which the outer wall of the resting body cracks and a discharge tube is formed, the resting body then functioning as a sporangium.

Catenaria anguillulae.

4. Those in which the resting body germinates to form cystospores, each of which gives rise to four uninucleate gametes which emerge through a pore.

Catenaria allomycis, Blastocladiella cystogena, Allomyces cystogenus.

5. Those in which the wall cracks open irregularly, papillae are formed, and zoospores are liberated; and those in which no details of wall cracking are available.

Allomyces arbusculus, A. javanicus, Blastocladia parva.

Monoblepharidales

Germination in this Order has been seen in five species belonging to two genera.

Where it has been noted, the resting period of the zygote before germination is about a month. These five species appear to fall into two groups:

1. Those in which the resting spore germinates by the cracking of the oospore wall and the production of a hypha or a mycelium (Sparrow, 1933).

Monoblepharis macrandra, M. polymorpha, Monoblepharella taylori, M. mexicana.

2. That one in which a hypha passes to the outside through a pore in the oogonial wall and then forms a mycelium.

Monoblepharella elongata.

It is impossible to compare this group with the Blastocladiales as no details of the wall cracking seem to have been recorded. Also there appears to be no recorded stage in the germination process.

Of the species mentioned above, *M. polymorpha* germinates by producing a hypha. It may possibly be that this would later develop into a mycelium.

Hypochytriales

Only one example of germination was found in this Order. In *Hypochytrium hydrodictii* the resting body forms a single discharge papilla through which the spores are liberated.

Leptomitales

There are three examples of germinating oospores in this Order. In all three examples, the germinating oospore produces one or more slender hyphae. These forms are:

Apodachlya brachynema, A. minima, Apodachlyella completa.

The stages of germination have been observed by Coker and Leitner (1938) in *A. minima:*

1. Cytoplasm becomes irregular in outline where pressed against the oil droplet and a few patches of small granules appear in the hyaline cytoplasm.
2. Cytoplasm becomes granular throughout.
3. Egg enlarges and splits oogonial wall.
4. One or two germ tubes formed which fill with cytoplasm.
5. Meanwhile, oil globule diminishes in size and is apparently used up.
6. When egg is empty, backflow into egg is prevented by the formation of a plug.

Several of these stages are found in the germinating resting bodies of other Orders. The breaking down of the oil globules and the darkening cytoplasm recall the series of events in the Chytridiales and the Saprolegniales.

Lagenidiales

There are four examples of germinating bodies in this Order. These are: *Olpidiopsis achlyae, O. varians, O. schenkiana, Lagenidium rabenhorstii.*

In the first three of the examples, the resting body functions as a sporangium with a short germination tube from which several spores are discharged. The last case, *L. rabenhorstii,* is rather unique. Twenty-four hours after wall formation on the resting spore, it breaks down and liberates a single spherical zoospore. However, as Sparrow (1943) says, "Although the quick germination of resting

structures is recorded in other fungi, the 'breaking down' of the wall and, in particular, the highly inefficient process of liberating only a single zoospore from a sexually formed structure are rare, if not unknown, among these plants and need confirmation."

No details of the germination process for any of the species have been found.

Peronosporales

Several examples of resting spore germinations are recorded for this Order. The species seem to fall into the following four groups:

1. That one in which the egg, after resorption of its wall and oil globule, functions as a sporangium.

Pythiogeton utriforme.

2. Those in which the oospore forms one or more branched hyphae.

Pythiomorpha gonapodyides, Pythium adhaerens, P. angustatum, P. ultimum.

3. Those in which the oospore forms a germ tube with an apical sporangium, or, certain branches of the germ tube form sporangia.

Pythium adhaerens, P. angustatum, P. dictyosporum.

4. That one in which the epispore and surrounding colorless membrane breaks irregularly and the endospore bulges out, forming a sporangium.

Cystopus candidus.

Whenever the stages of germination were noted they agree in the following facts (Trow, 1901; Sparrow, 1931):

1. The inner wall of the oospore was dissolved.
2. The fatty mass was broken up.
3. The protoplasm increased in amount.
4. One or more germ tubes arose from the germinating eggs.

The same stages named above are also found in the germinating resting bodies of the Chytridiales and Saprolegniales.

GENERAL REMARKS ON GERMINATION IN THE PHYCOMYCETES

From what has been presented on the preceding pages, certain general statements can be made concerning germination in this class of fungi.

1. The outer wall of the resting body is pierced by a long or short discharge tube, or cracked during the germination process.

2. The inner layer of the resting body or the thinned zygote wall protrudes through the outside wall either in the form of papillae or germination tubes.

3. Whenever fatty reserve is found in the resting body, either in one single drop, or several globules, it is always broken up into recognizable smaller particles or disintegrated.

4. In general, the following types of germination are seen in the Phycomycetes:

A. Those in which the resting body is transformed into a sporangium which discharges spores.

Chytridiales:—*Diplophlyctis intestina, Rhizophydium ovatum, R. transversum, R. messanense, Olpidium luxurians, Pringsheimiella dioica, Rozella allomycis, R. achlyae, Cladochytrium replicatum.*

Blastocladiales:—*Blastocladiella* sp., *Blastocladia pringsheimii*, *B. parva*, *Coelomomyces* sp., *Catenaria anguillulae*, *C. allomycis*, *Allomyces* sp.

Hypochytriales:—*Hypochytrium hydrodictii*.

Saprolegniales:—*Achlya flagellata*, *A. orion*.

Lagenidiales:—*Olpidiopsis achlyae*, *O. varians*, *O. schenkiana*.

Peronosporales:—*Pythiogeton utriforme*.

B. Those in which the resting body functions as a prosporangium.

Chytridiales:—*Rhizidium mycophilum*, *Polyphagus euglenae*, *Rhizophydium Couchii*, *Entophlyctis vaucheriae*, *Endochytrium* sp., *Diplophlyctis intestina*, *Megachytrium westonii*, *Chytrium olla*, *C. schenkii*, *C. lagenaria*, *Rhizidiopsis emmanuelensis*, *Phlyctochytrium synchytrii*, *Micromyces longispinosus*, *Blyttiomyces spinulosus*, *Rhizosiphon crassum*, *Septochytrium variabile*.

Peronosporales:—*Cystopus candidus*.

C. Those in which the resting body forms a short or long germ tube with apical sporangium (ia), or, a branched tube with certain branches forming sporangia.

Saprolegniales:—*Aplanes treleaseanus*, *Saprolegnia ferax*, *S. delica*, *S. megasperma*, *S. diclina*, *S. litoralis*, *Achlya colorata*, *A. racemosa*, *A. flagellata*, *A. proliferoides*, *A. americana*, *A. caroliniana*, *A. apiculata*, *A. recurva*, *A. glomerata*, *A. crenulata*, *Isoachlya itoana*, *I. unispora*, *Aphanomyces laevis*.

Peronosporales:—*Pythium adhaerens*, *P. angustatum*, *P. dictyosporum*.

D. Those in which the resting body forms a long or short germ tube, or a branching mycelium.

Chytridiales:—*Zygochytrium aurantiacum*.

Monoblepharidales:—*Monoblepharis macrandra*, *M. polymorpha*, *Monoblepharella taylori*, *M. mexicana*, *M. elongata*.

Saprolegniales:—*Isoachlya unispora*, *I. intermedia*, *Aphanomyces laevis*, *Brevilegnia linearis*, *Geolegnia inflata*, *Achlya glomerata*.

Peronosporales:—*Pythium adhaerens*, *P. angustatum*, *P. ultimum*, *Pythiomorpha gonapodyides*.

The writer made the above study in an endeavor to ascertain whether any phylogenetic relationships between the members of the Saprolegniaceae and other Phycomycetes could be made out. As can be seen the results are inconclusive. It can be pointed out, however, that as a rule the wall of the resting spore in the Chytrids and Saprolegniales is digested internally and a pore or a germ tube is formed, while the frangible wall of the Blastocladiales is generally cracked.

SUMMARY

The zygotes of twenty-six species of the Saprolegniaceae have been germinated and their germination processes followed through in detail. Of these twenty-six, only four have been followed through in some detail by other observers. Six other observers have mentioned seeing the germinated zygote in six species but no details of development were given. The zygotes of the Saprolegniaceae will germinate after a rest period if the mycelium is placed in fresh

charcoal distilled water. It was necessary to employ a special decoction (corn-grain juice) in only two species of the twenty-six, *I. itoana* and *I. intermedia.*

The germinated zygotes fall into four types:

A. Those in which a long or short germ tube is formed with an apical sporangium. The following forms are included in this type: *Aplanes treleaseanus, Saprolegnia delica, S. ferax, S. megasperma, S. diclina, S. litoralis, Achlya colorata, A. racemosa, A. flagellata, A. proliferoides, A. americana, A. caroliniana, A. apiculata, A. recurva, A. glomerata, A. crenulata.*

B. Those in which the germ tube produces a sparsely branched mycelium with a sporangium at the apex of the main hypha or a branch. This type includes: *Isoachlya unispora, I. intermedia, I. itoana, Achlya americana, Aphanomyces laevis.*

C. Those in which the primary germ tube forms a branched mycelium. This group includes: *Isoachlya unispora, I. intermedia, Achlya glomerata, Aphanomyces laevis, Brevilegnia linearis.*

D. Those in which the primary germ tube forms a long unbranched hypha. These are: *Aphanomyces laevis, Brevilegnia linearis, Geolegnia inflata.*

The food material contained within the egg has been proved to be true fat in *Achlya flagellata, A. apiculata,* and *Saprolegnia ferax.*

Experiments involving the effects of pH on germination have demonstrated that low pH's and alkaline solutions tend to inhibit germination; that the low pH ranges tend to cause the germinating eggs to deviate from their usual development in fresh water; and that eggs in a pH of 6.9 undergo the same development as they do in fresh water.

An experiment, repeated several times, on the effect of light on germination has demonstrated that at least for the three species used in the experiment light is necessary for germination.

A study of the germinating resting bodies of other Phycomycetes has been made and these show various patterns of germination. These patterns, however, show no phylogenetic connections between the members of the Saprolegniaceae and other Phycomycetes as far as resting body germination is concerned.

It has been shown that the zygotes of the Saprolegniaceae can be germinated easily. These forms are large and easily grown. It is suggested, therefore, that they might lend themselves readily to experiments involving x-ray, exposure to ultra-violet light, and general genetical studies.

ACKNOWLEDGMENTS

I am deeply indebted to Dr. J. N. Couch, who suggested this problem, for his aid and encouragement during this study and to Dr. W. C. Coker for his continued interest. I also wish to thank Mrs. C. D. Beers for help in arranging the plates.

LITERATURE CITED

COKER, W. C. 1923 The Saprolegniaceae. University of N. C. Press. Chapel Hill, N. C.

——— AND COUCH, J. N. 1924 Revision of the Genus *Thraustotheca* with a Description of a New Species. Jour. Elisha Mitch. Sci. Soc. **40**: 197–202.

——— AND LEITNER, JANE. 1938 New Species of *Achlya* and *Apodachlya*. Jour. Elisha Mitch. Sci. Soc. **54:** 311–318.

——— AND MATTHEWS, V. D., AND [bibliog.] BARNHART, J. H. 1937 North American Flora II: part 1.

COUCH, J. N. 1926 Heterothallism in *Dictyuchus*, a genus of the water molds. Ann. Bot. **40:** 849–881.

——— AND WHIFFEN, A. J. 1942 Observations on the Genus *Blastocladiella*. Amer. Jour. Bot. **29:** 582–591.

DE BARY, ANTON. 1860 Einige neue Saprolegnieen. Jahr. f. Bot. **2:** 169–192.

——— 1863 Recherches sur le Developpement de Quelques Champignons. Ann. d. Sci. Nat., 4 Ser. **20:** 1–148.

——— 1884 Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria. English Edition. Clarendon Press. Oxford.

——— 1888 Species der Saprolegnieen. Bot. Zeitung **46:** 646–659.

FITZPATRICK, H. M. 1930 The Lower Fungi. McGraw-Hill Book Co. Inc., New York.

INDOH, H. 1939 Studies of the Japanese Aquatic Fungi. I. On *Apodachlyella completa* sp. nov. with a Revision of the Leptomitaceae. Science Reports Tokyo Bunrika Daigaku **4:** no. 66, 43–50.

JONES, R. J. AND DRECHSLER, C. 1925 Root Rot of Peas in the U. S. Caused by *Aphanomyces euteiches* (N. Sp.). Jour. Agric. Res. **30:** no. 4, 293–325.

KARLING, J. S. 1939 Studies of *Rhizophidium*. III. Germination of the Resting Spores. Bull. Torrey Bot. Club **66:** 281–286.

KASANOWSKY, V. 1911 *Aphanomyces laevis* de Bary. I. Entwicklung der Sexualorgane und Befructung. Ber. d. Deutsch. Bot. Ges. **29:** 210–228.

KLEBS, GEORGE. 1899 Zur Physiologie der Fortpflanzung einiger Pilze. II. *Saprolegnia mixta* de Bary. Jahr. f. Bot. **33:** 513–593.

LATHAM, D. H. 1935 *Achlya recurva* Cornu from North Carolina. Jour. Elisha Mitch. Sci. Soc. **51:** 152–156.

LEE, B. 1946 The Microtomist's Vade-Mecum. 10th Ed. The Blakiston Co., Philadelphia, Pa.

LAIBACH, F. 1926 Zur Cytologie von *Monoblepharis*. Ber. d. Deutsch. Bot. Ges. **44:** 59–63.

MATTHEWS, V. D. 1931 Studies on the Genus *Pythium*. University of N. C. Press, Chapel Hill, N. C.

PATTERSON, P. M. 1927 Fertilization in *Achlya colorata*. Jour. Elisha Mitch. Sci. Soc. **42:** 108–120.

PRINGSHEIM, N. 1873–1874 Weitere Nachtrage zur Morphologie und Systematik der Saprolegnieen. Jahr. f. Bot. **9:** 191–234.

RAWLINS, T. E. 1933 Phytopathological and Botanical Research Methods. John Wiley and Sons, New York, N. Y.

SCHLOSSER, L. A. 1929 Geschlechtverteilung und Fakultative Parthenogenese bei Saprolegniaceen. Planta Archiv. f. Wiss. Bot. **8:** 529–570.

SCHRADER, E. 1937–1938 Die Entwicklung von *Thraustotheca clavata*. Flora N. F. **32:** 125–150.

SHANOR, L. 1942 A New *Monoblepharella* from Mexico. Mycologia **34:** 241–247.

——— and Conover, Robert A. 1942 A New *Protoachlya*. Amer. Mid. Nat. **28:** 746–751.

SMITH, G. M. 1938 Cryptogamic Botany Vol. 1. McGraw-Hill Book Co., Inc., New York, N. Y.

SOROKINE, N. 1876 Quelques Mots sur le Developpement de L'*Aphanomyces stellatus*. Ann. d. Sci. Nat., 6 Ser. **3:** 46–52.

SPARROW, F. K. 1931 Two New Species of *Pythium* Parasitic in Green Algae. Ann. Bot. **45:** 257–277.

——— 1931 Observations on *Pythium dictyosporum*. Mycologia **23:** 191–203.

——— 1933 The Monoblepharidales. Ann. Bot. **47:** 517–542.

——— 1943 Aquatic Phycomycetes. University of Michigan Press. Ann Arbor, Michigan.

SPRINGER, M. E. 1945 Two New Species of *Monoblepharella*. Mycologia **37:** 205–216.

TROW, A. H. 1895 The Karyology of *Saprolegnia*. Ann. Bot. **4:** 609–650.

——— 1899 Observations on the Biology and Cytology of a new variety of *Achlya americana*. Ann. Bot. **13:** 131–179.

——— 1901 Observations on the Biology and Cytology of *Pythium ultimum* n. sp. Ann. Bot. **15:** 269–312.

WAGER, H. 1896 On the Structure and Reproduction of *Cystopus candidus* Lév. Ann. Bot. **10:** 295–342.

WESTON, W. H. 1918 The Development of *Thraustotheca*, a Peculiar Water-Mould. Ann. Bot. **32:** 156–170.

WHIFFEN, A. J. 1943 New Species of *Nowakowskiella* and *Blastocladia*. Jour. Elisha Mitch. Sci. Soc. **59:** 37–43.

——— 1946 Two New Terricolous Phycomycetes belonging to the Genera *Lagenidium* and *Blastocladia*. Jour. Elisha Mitch. Sci. Soc. **62:** 54–58.

WOLF, F. A. AND WOLF, F. T. 1947 The Fungi. Vols. 1, 2. John Wiley and Sons, Inc. New York, N. Y.

WOLK, F. T. 1944 The Aquatic Oomycetes of Wisconsin. Part 1. University of Wisconsin Press. Madison, Wisconsin.

ZIEGLER, A. W. 1948 A New Species of *Achlya*. Mycologia. May–June Issue 1948—forthcoming.

EXPLANATION OF PLATES

Figures made with the aid of a camera lucida; arm at 120 mm., and mirror at 45°, with paper at table level. Magnification 1128 × unless otherwise indicated. Drawings reduced about one half.

PLATE 1

Aplanes treleaseanus (Humphrey) Coker.

Fig. 1. Oogonium with five eggs.

FIGS. 2-6. Stages in germination.

Fig. 7. Germ tube with apical sporangium.

Fig. 8. Same, but with spores delimited.

Fig. 9. Low power view, 178 ×, of another oogonium showing the germinated eggs.

Saprolegnia ferax (Gruith.) Thuret.

FIG. 10. Oogonium, three eggs disintegrating.

Figs. 11–14. Stages in germination.

Fig. 15. Germ tubes from two germinating eggs passing to outside through oogonial wall pits.

Fig. 16. Empty sporangia of the above.

PLATE 2

Fig. 1. *Saprolegnia megasperma* Coker. Germinated egg with germ tube and apical sporangium.

Fig. 2. Same. Three sporangia formed. Note absence of cross wall.

Fig. 3. *Saprolegnia litoralis* Coker. Germinated eggs with germ tubes and apical sporangia.

Fig. 4. *Saprolegnia delica* Coker. Oogonium in which four eggs have germinated. Note germ tubes and sporangia.

Fig. 5. *Saprolegnia diclina* Humphrey. Germinated eggs with germ tubes.

Fig. 6. Same. Empty sporangium.

Isoachlya unispora Coker and Couch.

Fig. 7. Oogonium with egg.

Figs. 8–10. Stages in germination.
Fig. 11. Germ tube has passed through oogonial wall pit to outside.

PLATE 3

Fig. 1. *Isoachlya unispora* Coker and Couch. Germinated egg with long germ tube and apical sporangium. Note proliferation of sporangia.
Fig. 2. *Isoachlya intermedia* (Coker and Harv.) Coker. Germinated egg with long germ tube showing sporangium formation and sparsely branched mycelium; oogonium in outline.
Achlya colorata Patterson.
Fig. 3. Oogonium with three eggs.
Figs. 4–6. Stages in germination.
Fig. 7. Beginning of germ tube.
Fig. 8. Germ tube passing to outside.

PLATE 4

Fig. 1. *Achlya colorata* Patterson. Germinated egg showing germ tube with apical sporangium.
Fig. 2. *Achlya racemosa* Hildebrand. Germinated egg with germ tube and apical sporangium which has discharged spores.
Achlya flagellata Coker.
Fig. 3. Oogonium with three eggs.
Figs. 4–7. Stages in germination.
Fig. 8. Beginning of germ tube.
Fig. 9. Germ tube passing through oogonial wall. Note constriction of the tube as it passes through the wall.
Fig. 10. Germinated egg showing long germ tube and apical sporangium.
Fig. 11. *Achlya caroliniana* Coker. Germinated eggs showing long germ tubes with sporangia.
Achlya americana Humphrey.
Fig. 12. Germ tube from a germinated egg of *A. americana* which has produced an apical sporangium.
Fig. 13. Same. Low power view, 85 ×, of a germinated egg which has formed a sparsely branched mycelium with an apical sporangium at the end of the main hypha.

PLATE 5

Fig. 1. *Achlya glomerata* Coker. Low power view, 178 ×, of an egg which has germinated to produce a long branched mycelium.
Fig. 2. Same. Another egg which has germinated to produce a long germ tube with an apical sporangium.
Fig. 3. *Achlya crenulata* Ziegler. Germinated eggs which have produced germ tubes. The one on the right has formed an apical sporangium.
Fig. 4. *Achlya recurva* Cornu. Germinated egg which has produced a long germ tube. End of germ tube is swelling preparatory to sporangium formation.
Fig. 5. *Achlya apiculata* de Bary. Low power view, 178 ×, of an oogonium in which four eggs have germinated. Three have formed germ tubes with sporangia, while the fourth has produced a long unbranched hypha.
Protoachlya hypogyna Shanor and Con.
Fig. 6. Two germinated eggs from a single oogonium showing the germ tubes leaving the oogonium.
Figs. 7–8. The ends of the germ tubes shown in figure 6. The tubes were extremely long and would extend the full length of the plate before the portions shown here would be formed.

Fig. 9. *Thraustotheca clavata* (de Bary) Humphrey. A germinated egg showing the germ tube with cytoplasm collecting in the far end.
Fig. 10. Same. The completed sporangium.
Fig. 11. *Aphanomyces laevis* de Bary. A single egg has germinated forming a long branched mycelium. 85 ×.

PLATE 6

Fig. 1. *Thraustotheca primoachlya* Coker and Couch. Germinated egg with germ tube and apical sporangium.
Dictyuchus missouriensis Couch.
Fig. 2. Oogonium.
Figs. 3–5. Stages in germination.
Fig. 6. Germ tube passing through the oogonial wall to the outside.
Fig. 7. Germinated egg with long germ tube and apical sporangium.
Brevilegnia linearis Coker and Braxton.
(Magnification 1816 × unless otherwise indicated.)
Fig. 8. Oogonium.
Figs. 9–12. Stages in germination.
Fig. 13. Germ tube passing through oogonial wall.
Fig. 14. Tube growing in length.
Fig. 15. Germinated egg with a single long unbranched hypha.
Fig. 16. Another germinated egg which has produced a short, branched germ tube.
Geolegnia inflata Coker and Harvey.
(Magnification 1816 × unless otherwise indicated.)
Fig. 17. Oogonium.
Figs. 18–20. Stages in germination.
Fig. 21. Germ tube passing from oogonium.
Figs. 22–23. Two examples of germinated eggs. Note long unbranched germ tube. 178 ×.

PLATE 1

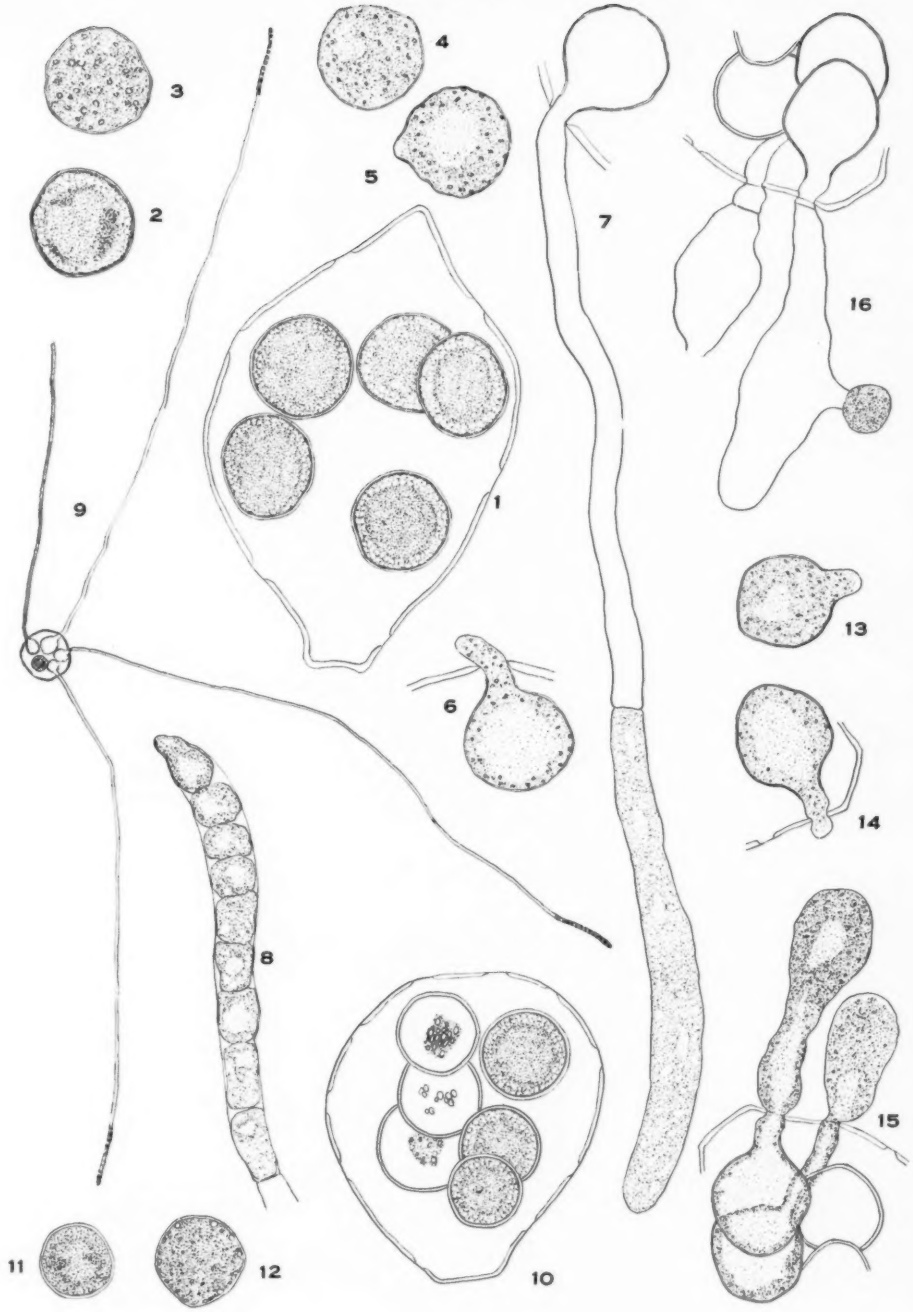
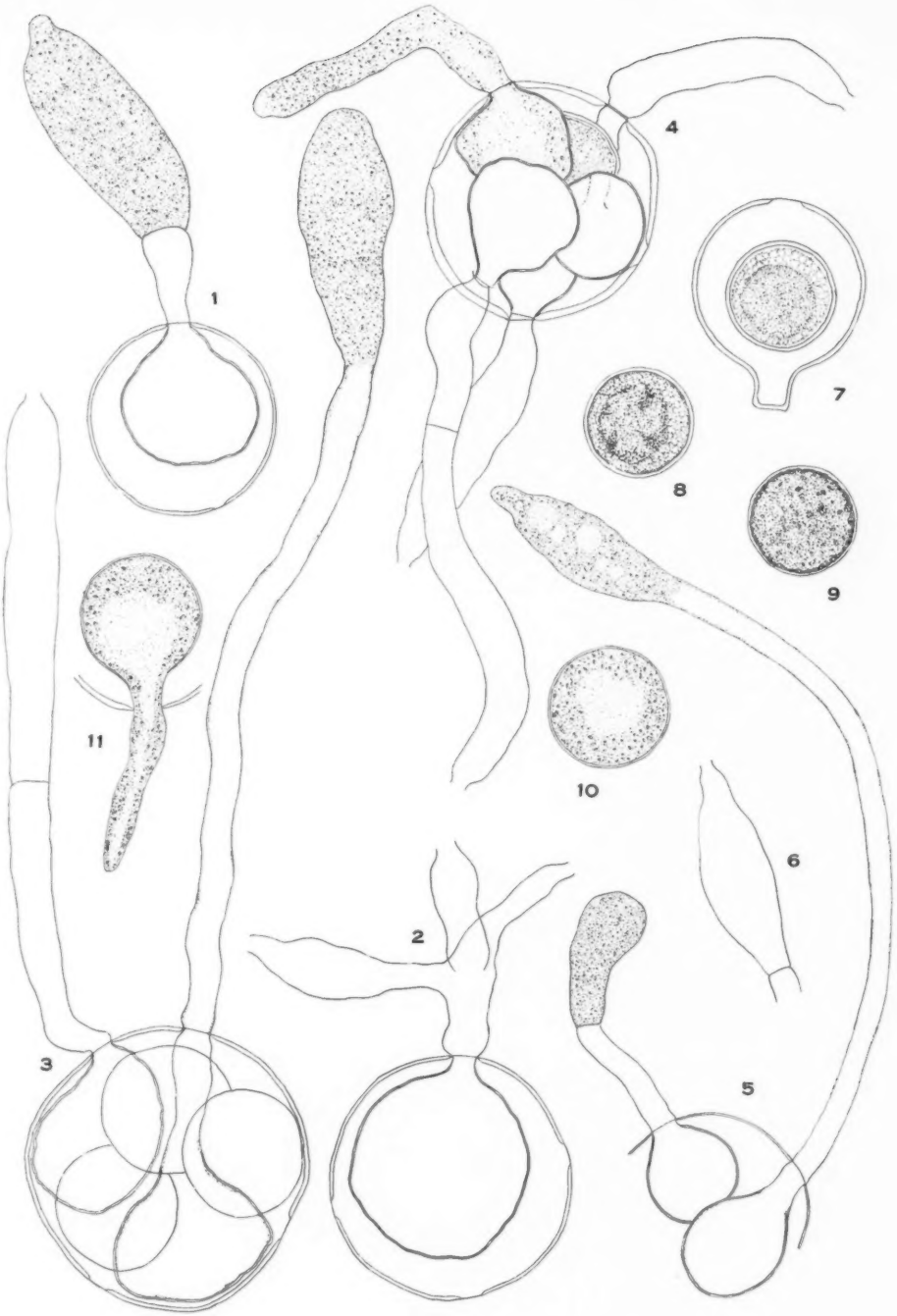


PLATE 2



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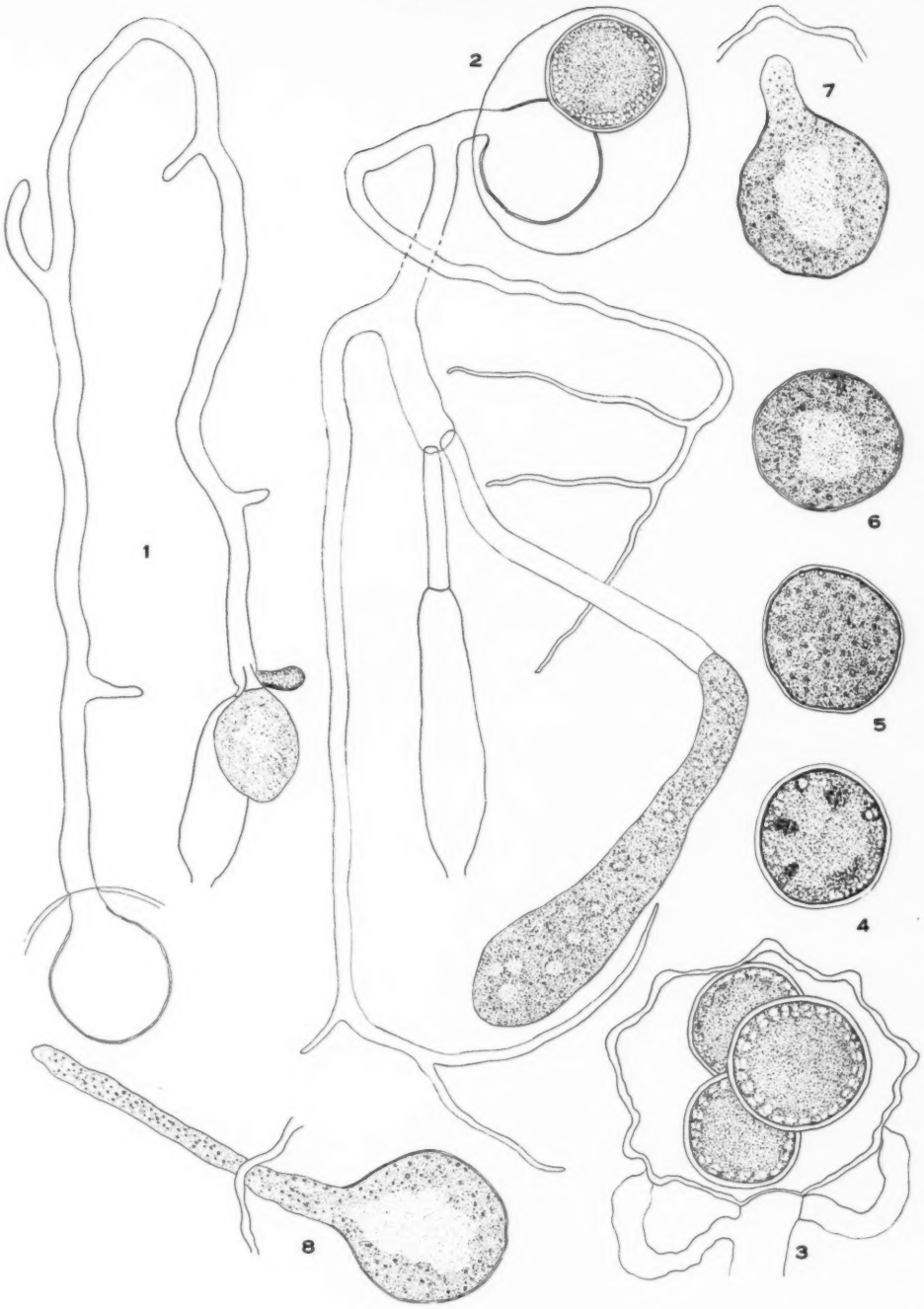

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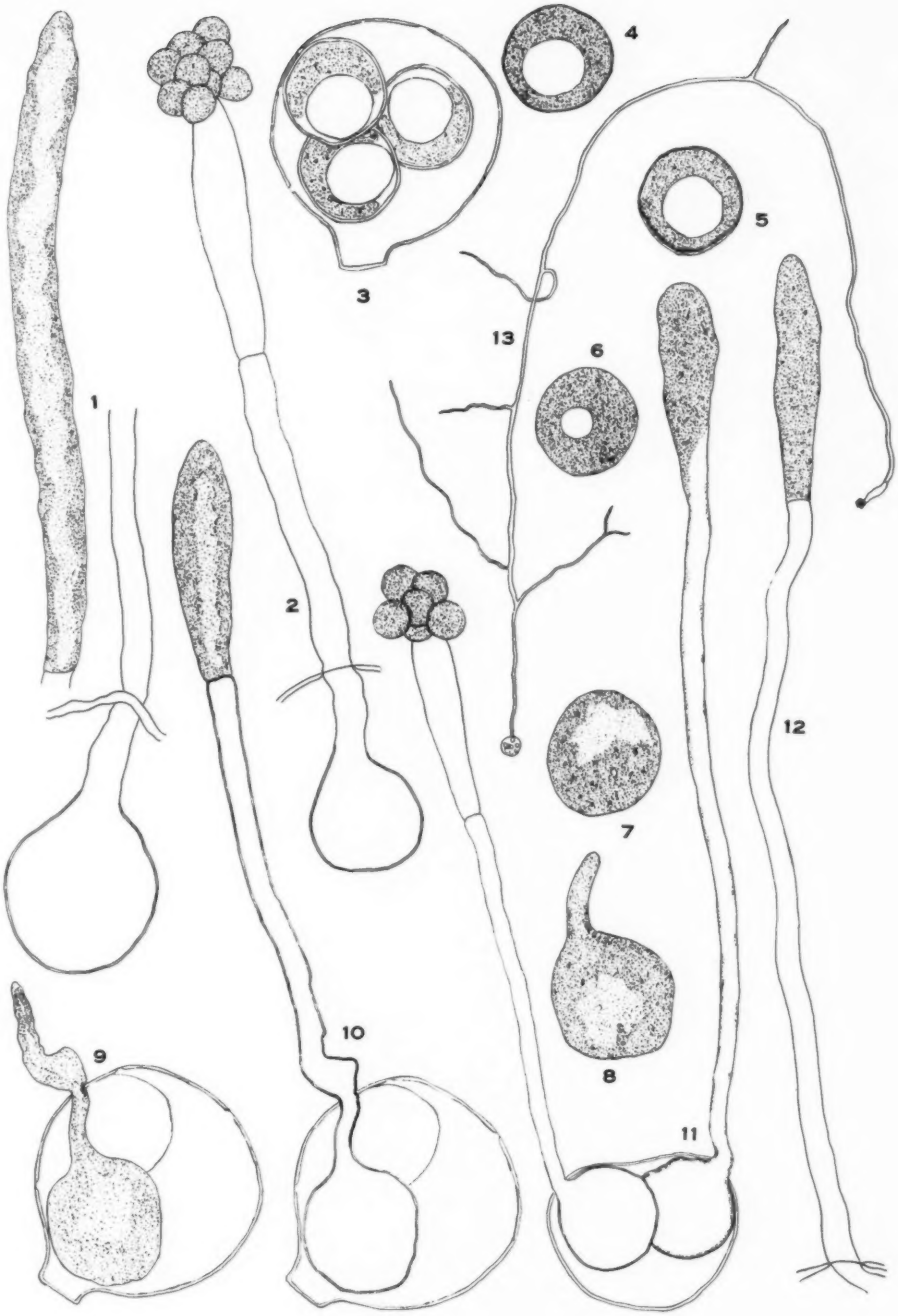

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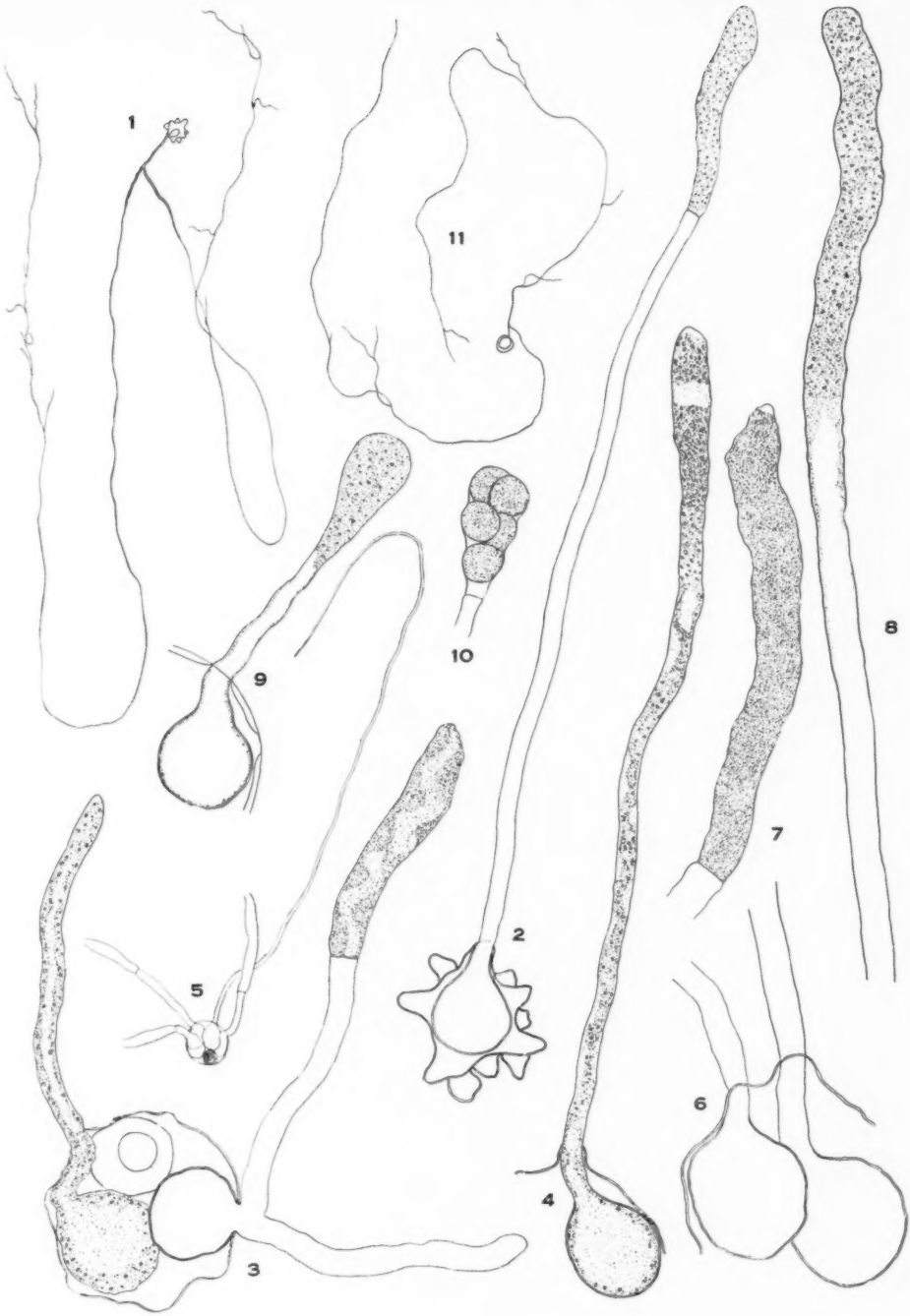
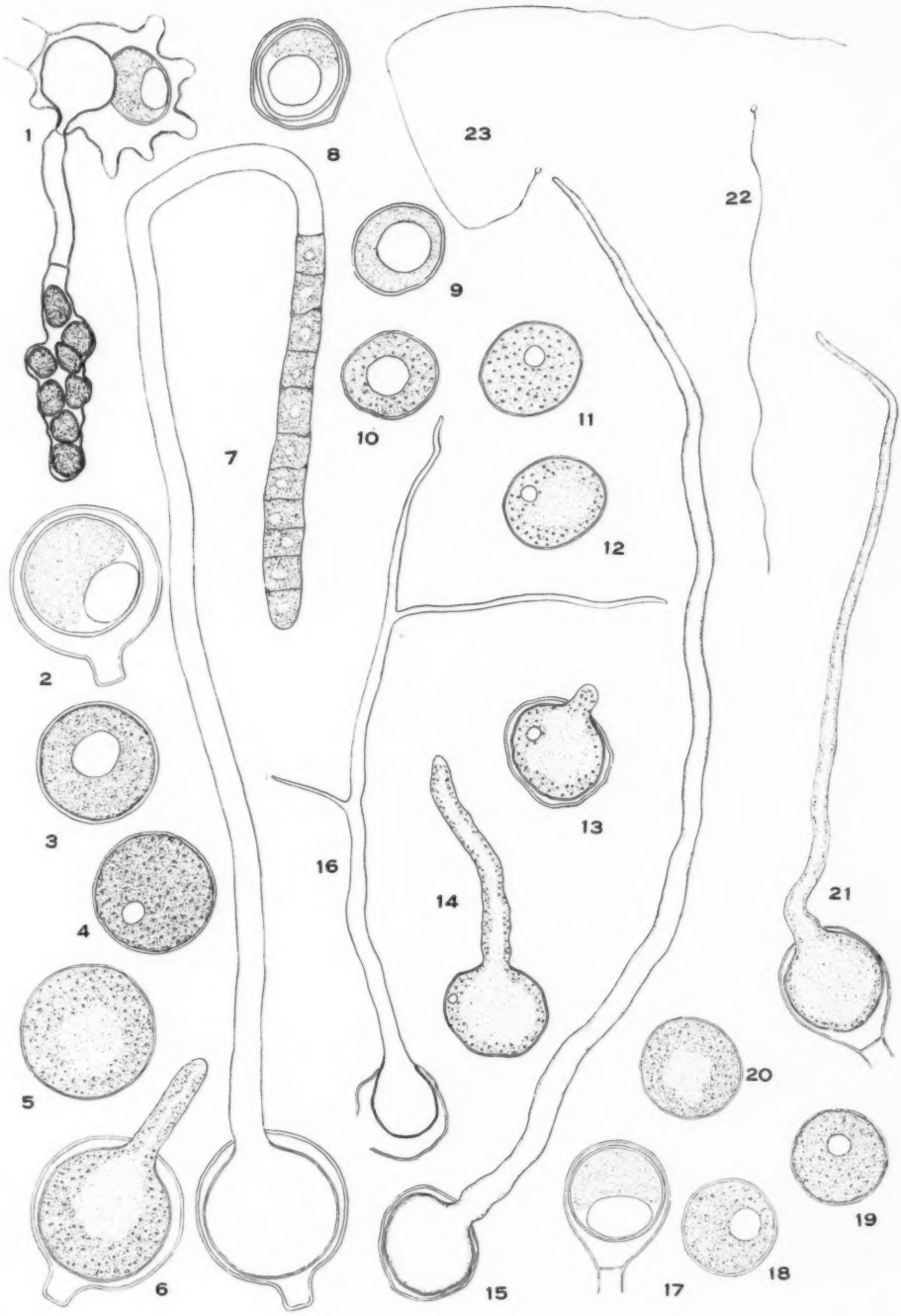


PLATE 6



THE BASKING SHARK, *CETORHINUS MAXIMUS*, ON THE NORTH CAROLINA COAST

By E. W. Gudger

American Museum of Natural History
New York City

Plate 7

In 1935, the late H. H. Brimley published in the Mitchell Journal the first records of the occurrence on the North Carolina coast of the two largest sharks that are found in the Atlantic or in any other ocean. One was the Whale Shark, *Rhineodon typus*, the largest of all sharks. This shark, in contrast to the Basking Shark, is very large in the head and shoulders region, has a broad flat head with a terminal mouth beset with many short recurved teeth, and with relatively small or at any rate moderately sized gill slits. The broad head is covered with small and irregularly placed white spots but on the sides of the body the spots are large and set in checker-board squares. The Whale Shark is an inhabitant of tropical and warm-temperate seas. This specimen had drifted north with the Gulf Stream and had become stranded June 6, 1934, on a shoal in Southport Harbor, and at that time was the most northerly known specimen. It was not measured but was estimated to be 40 feet long.

The other big shark recorded by Brimley was the Basking Shark, *Cetorhinus maximus*. This large fish is an inhabitant of cold oceanic waters. In the north Atlantic it is found off the western and northern coasts of Ireland and Scotland, off the eastern coast of Scotland and England, off the Western coast of Norway, and around Iceland. In the western North Atlantic, it comes south in the cold water between the Gulf Stream and the American coast. It was formerly abundant in New England waters (especially in the Gulf of Maine). Occasional specimens are taken off Long Island and along the New Jersey coast. There seems to be no record of its capture in Maryland or Virginia waters, but three records (one old and two new) are now at hand for its occurrence on the North Carolina coast.

Cetorhinus, grayish-brown or slaty in color, is a much slenderer shark than Rhineodon. It has a pointed head (like the pointed nose of a bullet in a long cartridge) and a ventral mouth, wide for a shark with a pointed nose. The numerous teeth are small and recurved. Cetorhinus is particularly notable for its enormously long gill slits, which almost surround the neck. They begin well up on the dorsum, and those of one side nearly meet on the ventral surface those of the other side. The tail is lunate, the lower lobe being somewhat smaller than the upper. That this shark and its distinctive characters may at this point be made clear to the reader, Figure 1 is introduced here. Its source will be explained later. Like the Whale Shark, the Basking Shark grows to at least 45 feet and numerous specimens of 28 to 35 feet have been measured in New England waters. From this it is clear that the fish is not inaptly named *maximus*. As

will now be seen, our three specimens are relatively small and hence are young fish.

THREE BASKING SHARKS IN OUR COASTAL WATERS

Basking Shark No. I—H. H. Brimley (1935) wrote thus of this specimen: "On Feb. 12, 1935, a female specimen . . . was taken in a shad net about two miles outside Corncake Inlet, . . . a small channel connecting the Cape Fear River with the ocean a few miles below Fort Fisher" [on the south side of the Cape Fear estuary]. This, so far as the available records go, is the farthest south in the western Atlantic for Cetorhinus.

Its measurements were: length 13 feet, 5 inches from tip of snout to tip of tail; greatest girth: 53 inches; caudal fin from tip to tip of lobes, 41 inches; width of mouth, across from angle to angle, 18 inches; weight of liver (mostly oil) 65 pounds; weight of fish estimated at about 600 pounds; recurved teeth about one-sixteenth of an inch long; length of gill slits not given.

In order accurately to locate the places of capture of the two 1947 basking sharks, it will be necessary just here to get a clear idea of the coast line of North Carolina from Cape Lookout west and south. From the base of the Cape, the coast (as Shackleford Banks) trends roughly west to Beaufort Inlet, and from Beaufort Inlet, as Bogue Banks, it swings slightly south of west to the localities to be noted where sharks II and III were captured.

Basking Shark No. II—Notice of the capture of and most of the data for this specimen were sent me by Mr. J. W. Bailey, Jr., of Morehead City, N. C., which is situated on the mainland about opposite Beaufort Inlet.

This big fish was taken April 25, 1947, in the Atlantic about half a mile out from Hoop Pole Woods on Bogue Banks, about 10 miles west of Beaufort Inlet. It was captured by Capt. Leo Gillikin of Morehead City in his sinknet fishing boat. This big and logy shark is not much of a fighter, but by its very size and weight, when entangled in the sinknet, it destroyed about 50 yards of this, entailing considerable loss to the fishermen. Fortunately for science, Capt. Gillikin brought this basking shark into Morehead City, where it was an object of much interest.

It was measured over the curves of the body and found to be 13 feet, 6 inches long. Between perpendiculars it would quite surely measure about 13 feet. No scales were available for weighing, but its weight was estimated at about 1300 pounds. A number of photographs were taken. The best (unfortunately with a "gallery" behind it) in left frontal oblique view shows the great size of the fish. The upper jaw being held up by a hook and a rope passing over an overhead pulley, the photograph (kindly sent me by Mr. Aycock Brown) shows the stubby pointed snout, the large wide and vertical gape of the open mouth, and the enormous gill arches. These it may be remarked are the largest and longest found in any shark.

So far as I have found, there has never been published any portrayal by camera or drawing of the inside of the mouth of Cetorhinus showing the huge gill arches.

I had wished to use the photograph referred to, but it would require much work by an artist to remove the "gallery". Fortunately there was procured by the American Museum of Natural History in 1930 a splendid Cetorhinus taken on the New Jersey coast. It came to us from the fish freezer at Long Branch frozen as solid as a log. When it had thawed out, I had an extensive series of photographs taken of it. Among them that reproduced herein as Figure 1, which shows the fish in side view; and Figure 2, which shows the interior of the mouth and particularly the huge gill arches. This shark was 14 feet, 3 inches between perpendiculars. Since the basking shark is known to reach a length of 45 feet (more than three times longer than the specimen whose mouth is shown in Figure 2) one can only imagine how gigantic its gill arches would be.

Mr. Bailey took some small photographs of this No. II specimen and of these enlargements have been made. One is an oblique-lateral view of the great fish lying on the wharf on its left side. Another is of the pelvic fins and the cloacal region. However, this latter lacks sharpness and contrast, and while it shows what looks very like a clasper, it leaves the sex a bit in doubt. But Mr. Bailey has sent me a sketch of the pelvic fins and the claspers as he saw them. This effectually settles the question that this shark was a male.

Basking Shark No. III—This fine specimen was called to my attention by Mr. Aycock Brown, formerly of Beaufort, but now of New Bern, N. C. It was taken April 25, 1947, by Capt. Gordon Lewis, a sinknet fisherman of Morehead City, in 40 feet of water about 2 miles off Salter Path on Bogue Banks, some 12 miles west of Beaufort Inlet. This shark in its struggles wrapped the lines of the net so tightly around it that it was dead when the fishermen got it out of the net. It is said to have measured 13 feet in length and is estimated to have weighed about 1300 pounds. This estimate is probably about double the actual weight.

Fortunately for this faunal record of the appearance of this fish in the coastal waters of North Carolina, Captain Lewis, with good judgment, brought his big fish to Morehead City, even though this involved towing this 13-foot shark, tail foremost, about 20 miles. What this means I well know, since at Key West years ago we had the "prodigious" task (as we thought) of towing 11-foot tiger sharks 4 miles from the place of capture to the dock where they could be measured and dissected. In Morehead City basking shark No. III was hung up by the tail and photographed. For a copy of the photograph I am indebted to Mr. Ottis Purifoy of Morehead City. This photograph, however, leaves the sex of the fish in doubt.

I had planned to reproduce this photograph herein to show the general form and make up of the shark, but the head is barely clear of the ground and below snout and mouth parts is a heavy shadow. Furthermore, due to the partial eversion of gullet and stomach after the shark had been hanging for some time, the lower mouth parts show as abnormal. These artifacts spoil the photograph for scientific purposes and to my regret it cannot be utilized. However, Figure 1 is made from a photograph which shows the make up of Cetorhinus in all points.

Cetorhinus maximus is called basking shark because of its habit of lying awash

at the surface of the sea with its big triangular dorsal fin standing high out of the water. It seems to be literally basking in the sunshine. Being gregarious in its habits, it is said to loaf often in the sunshine in small companies. Several writers have noted that two or three will sometimes swim in tandem fashion with their dorsal fins high out of the water—each observed occurrence possibly giving rise to another sea serpent story.

Possibly in this gregariousness is found the explanation that our basking sharks II and III were taken in the ocean about 2.5 miles apart off the western end of Bogue Banks, on April 25, 1947.

There are rumors of three other large sharks taken in the Cape-Lookout and Shackleford-Banks region this summer, and called basking sharks. But of these Mr. Bailey has not been able to get any definite descriptions, much less any photographs. And because of the newspaper notoriety of the capture of the two sharks referred to herein, it is probable that any large shark taken in this region this summer would be mistakenly called by the fishermen generally—"basking sharks." Hence, in the absence of proof, no notice can be taken of these three alleged sharks of that name.

The basking shark is valuable to shark fishery companies. The thick skin makes good leather, but is so thick that it has to be "split" to make it usable. Thus every skin makes two "sides" of leather for the trade. The meat is ground up for fertilizer. The liver is, as Brimley noted, heavily laden with oil. This when properly purified is used for treating leather for flexibility after tanning. I have somewhere read that years ago there was a basking shark fishery for the liver oil on the western coasts of Ecuador and Peru and a recent newspaper clipping states that at the present day an extensive fishery for Cetorhinus is carried on off the southern California coast.

PLATE 7

Figure 1. The Basking Shark, *Cetorhinus maximus*, in lateral aspect. Note the pointed head, the ventral mouth, the enormously long gill slits and flaps, the high dorsal fin, and the lunate tail fin with upper lobe the longer. Photograph A. M. N. H.

Figure 2. The Widely Opened Mouth of the Basking Shark. Note the huge gill arches, upper and lower, right and left. Contrast them with the gill slits seen in Figure 1. Note also the pointed snout and in the front upper mouth the oral breathing valve. Photograph A.M.N.H.

PLATE 7

1

2

THE VASCULAR FLORA OF THE OLIVINE DEPOSITS OF NORTH CAROLINA AND GEORGIA*

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Plate 8 and Three Text Figures

INTRODUCTION

A series of olivine and serpentine deposits are found in the Appalachian mountains from Alabama to Quebec. In North Carolina and Georgia there are 25 high-grade olivine deposits (Hunter, 1941). They are composed of nearly pure magnesium silicates. The high concentration of magnesium in the deposits and the apparent lack of other elements necessary for plant growth suggested that a study of the vegetation on the deposits might prove worthwhile.

No botanical work has been done previously on olivine. Several papers have been published on the flora of serpentine, which is a hydrated magnesium silicate. Schimper (1903) mentioned a few species of ferns characteristic of serpentine in Germany. Harshberger (1903) made an ecological study of the serpentine barrens of Pennsylvania. He found moisture relations the controlling factors in association and species distribution. Fernald (1907), in studying the soil preferences of alpine plants, found 21 vascular species on Mt. Albert, a serpentine mountain in Gaspé County, Quebec; these 21 species are not found elsewhere south of the St. Lawrence River. He also found that species characteristically growing on potassic rocks were dwarfed or stunted when growing on serpentine. However, the more distinctive plants on serpentine were luxuriant wherever there was sufficient moisture. Pennell (1910 and 1912), in a rather extensive study of the flora of the Conowingo Barrens (serpentine) of southeastern Pennsylvania, found 217 species characteristic of the serpentine, and 77 others occurring occasionally. Of those 217 species 17 were restricted to the Conowingo Barrens. Mason (1946) published his study of endemism on serpentine in California. At present, students at the University of California are working on the physiology of several species and the genetics of genera showing great speciation on serpentine.

The objectives of my investigation were to make a taxonomic study of the vascular flora of olivine deposits occurring in North Carolina and Georgia, and to correlate the species and community distribution with the mineral distribution. Nine high-grade olivine deposits in North Carolina and one in Georgia were selected for this study. Every community on each deposit was mapped and at least one or more specimens of every vascular species in each community was

* A thesis submitted to the Faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Botany.

collected for study. In order to compare the vegetation of the olivine deposits with that of the surrounding areas, two communities on soil derived from rock surrounding the olivine were studied in detail. Observations were made on the flora around the other deposits.

Field studies and collections were made on the ten deposits on the following dates: June 14 to July 13, 1946; August 23–26, 1946; September 6–7, 1946; October 18–20, 1946; May 28 to June 6, 1947; and August 18–23, 1947. Also during August 1947, observations were made on twelve other high-grade olivine deposits in North Carolina and Georgia.

LOCATION OF DEPOSITS

According to Pratt and Lewis (1905), a belt of basic magnesian rocks extends from east-central Alabama, 175 miles from the Gulf of Mexico, to the Gaspé

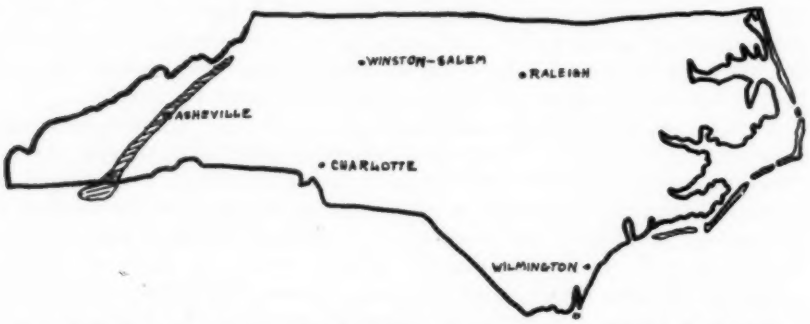

FIG. 1. Outline map of North Carolina showing approximate location of olivine belt.

Peninsula on the St. Lawrence River in Canada, a distance of more than 1600 miles. In North Carolina and Georgia the belt of olivine (basic magnesian rock) is approximately 15 miles wide and 175 miles long, with its widest part at the southern end in Georgia. It extends from Watauga County in North Carolina to White County in Georgia. The center of this belt is near Asheville, North Carolina (Fig. 1).

In 1941 Broadhurst (in Hunter) mapped 25 high-grade olivine deposits for the Tennessee Valley Authority. Of these 25 deposits I selected the following ten (Fig. 2) for botanical study:

Cane Creek—3½ mi. SE. of Sylva, Jackson Co., N. C.
Corundum Hill—1¼ mi. NW. of Gneiss, Macon Co., N. C.
Dark Ridge—½ mi. SW. of Balsam P. O., Jackson Co., N. C.
Day Book—3 mi. N. of Burnsville, Yancey Co., N. C.
Deposit No. 9—½ mi. SW. of Ellijay P. O., Macon Co., N. C.
Frank—Frank, Avery Co., N. C.
Holcombe Branch—1½ mi. N. of Democrat, Madison Co., N. C.
Laurel Creek—1½ mi. E. of Pine Mt., Rabun Co., Ga.
Newdale—1¾ mi. E. of Micaville, Yancey Co., N. C.

Newfound Gap—5 mi. NE. of the railroad station at Canton, Haywood-Buncombe Co. line, N. C.

SHAPE AND SIZE OF DEPOSITS

The deposits studied range in width from 250 to 1500 feet, and in length from 1000 to 3000 feet. The largest deposit is Holcombe Branch with an area of .202 square mile (129.28 acres), and the smallest is Newfound Gap with an area of .01 square mile (6.4 acres). The total area of the ten deposits is .453 square mile (290 acres). The areal extent of the deposits was determined by a grid system. The surface areas of the deposits form very irregular patterns (Fig. 3).

FIG. 2. Counties of western North Carolina showing locations of deposits studied.

GEOLOGY

Regional Geology

The olivine deposits of western North Carolina and northern Georgia are co-extensive with the crystalline rocks of the Appalachian Mountain System. The olivine and other basic magnesian rocks occur in a gneissic belt averaging 35 miles in width, bordered on the east and west by partially metamorphosed sedimentary rocks (Pratt and Lewis, 1905). These basic magnesian rocks form disconnected masses arranged in a line or series of parallel lines that coincide approximately in direction with the strike of the gneissic lamination, N 30° E. Most of the deposits have a sheath of schistose rocks separating them from the normal gneiss.

Hunter in 1941 stated that the deposits are thought to be intrusions that were part of an active pre-Cambrian volcanic system. Olivine deposits now exposed were probably crystallized and cooled at a depth greater than 10 miles below the

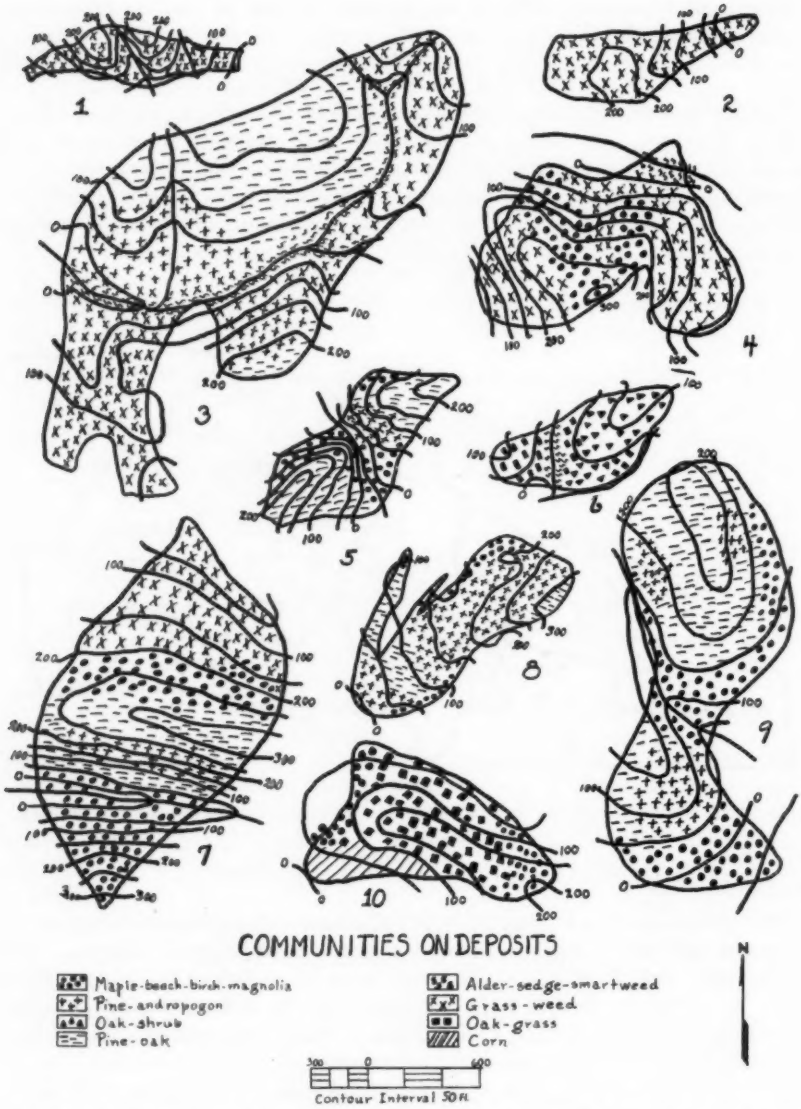

FIG. 3. 1, Cane Creek; 2, Newfound Gap; 3, Holcombe Branch; 4, Frank; 5, Day Book; 6, Newdale; 7, Dark Ridge; 8, Corundum Hill; 9, Laurel Creek; 10, No. 9.

surface at the time of their injection. During geological times, rocks and sediments to a depth of approximately 10 miles have been removed from this area by erosion.

Petrology

The deposits selected for study are composed of dunite and saxonite which are essentially pure olivine. Chromite is the primary accessory mineral of dunite, and bronzite is the primary accessory mineral of saxonite.

These deposits can be divided into two structural types, the ring dike, and the lens-shaped with its long axis parallel to the regional schistosity. Cooling joints and occasional faults are prominent features of the lens-shaped structure. The most noticeable feature of the ring dike is the parallel lamination which on a weathered surface has the appearance of a sandstone. Veins of different minerals are present in each deposit.

Chemical analyses of dunite and saxonite are given in Table II.

TABLE I

Size of Deposits

DEPOSIT	MAX. LENGTH	MAX. WIDTH	SQ. MI.	ACRES
Cane Creek	1500 ft.	350 ft.	0.016	10.24
Corundum Hill	1200 ft.	500 ft.	0.017	10.88
Dark Ridge	2000 ft.	900 ft.	0.047	30.08
Day Book	2000 ft.	600 ft.	0.035	22.40
Deposit No. 9	1000 ft.	800 ft.	0.02	12.80
Frank	1400 ft.	600 ft.	0.031	19.84
Holcombe Branch	3000 ft.	1500 ft.	0.202	129.28
Laurel Creek	2500 ft.	800 ft.	0.045	28.80
Newdale	1800 ft.	500 ft.	0.03	19.20
Newfound Gap	1000 ft.	250 ft.	0.01	6.40

Mineralogy

Olivine usually accounts for more than 60% of the minerals found in dunite and saxonite. Most of the olivine consists of 80% forsterite (Mg_2SiO_4), 11% or less fayalite (Fe_2SiO_4), and the remaining 9% or less of other magnesian minerals which are usually hydrates derived from olivine.

The high-grade olivine, 45% or more MgO, is usually found in the center of the deposits. The area on the deposits surrounding this high-grade olivine is composed mainly of faulted and partly serpentinized dunite and saxonite. Between the surrounding gneisses and schists, and the serpentinized dunite and saxonite, is a talcy vermiculite fringe zone a few feet in width (Hunter, 1941).

Listed below are the secondary magnesian and accessory minerals found on the deposits studied:

Anthophyllite	$(MgFe)_7Si_8O_{22}(OH)_2$
Bronzite	$(MgFe)SiO_3$
Chlorite	$(MgFe)_5(AlFe)_2Si_3O_{10}(OH)_8$
Chromite	$FeCr_2O_4$
Serpentine	$Mg_3Si_2O_5(OH)_4$
Talc	$Mg_3Si_4O_{10}(OH)_2$
Vermiculite	$(OH)_2(MgFe_2)(Si, Al, Fe)_4O_{10}\cdot 4H_2O$

(Minerals from Hunter, 1941; chemical formulae from Hurlbut, 1941).

TOPOGRAPHY

Most of the deposits studied occur as resistant ridges or as exposed outcrops on steep hillsides. Small streams have cut through the Dark Ridge, Day Book, and Laurel Creek deposits, forming olivine cliffs on either side, some of which rise as high as 375 feet above the stream level. The North Toe River cuts through the Frank Deposit. The deposits range in elevation from 1800 feet on Laurel Creek, lowest point on the deposit, to approximately 3250 feet on Newfound Gap.

SOILS

The deposits are characterized by numerous small boulders, and by depressions that are formed by chemical weathering. Residual clays occur in the joints and

TABLE II

Chemical Analysis of Rocks

Compiled from Hunter, 1941

ROCK	DEPOSIT	MgO	SiO_2	Fe_2O_3	Ti, Cr, Al (OXIDES)	CaO	IGN. LOSS	ALK.
Fine-grained Dunite (unaltered Olivine)	Day Book	49.31	40.86	7.66	2.18	0.00	0.63	
Fine-grained Saxonite (partly altered Olivine)	Day Book	45.92	42.40	8.62	1.06	0.00	1.23	
Coarse-grained Dunite (unaltered Olivine)	Dark Ridge	49.69	41.00	9.74	0.38	0.00	0.61	
Weathered Dunite	Dark Ridge	44.08	43.60	9.90	1.76	1.23	1.51	
Serpentinized Saxonite	Cane Creek	44.82	41.34	9.44	1.58	0.30	2.35	
Dunite: unaltered Olivine	Cane Creek	48.78	40.04	10.24	0.48	0.26	0.92	
Dunite: unaltered Olivine	No. 9	47.50	38.94	10.88	1.36	0.08	0.89	
Dunite: unaltered Olivine	Corundum Hill	49.35	40.58	8.30	0.65	trace	1.13	
Partly Serpentinized Dunite	Corundum Hill	45.46	41.60	8.46	1.70	trace	2.61	
Serpentinized Dunite	Laurel Creek	42.17	43.92	8.94	1.40	0.00	3.94	
Dunite (average of five commercial shipments)	Day Book	48.77	40.93	7.60	$\frac{Al_2O_3}{1.32}$	0.29	1.09	0.13

depressions. These reddish and yellowish clays are seldom over six inches deep except in a few joints or near the borders of deposits on slopes. There is no mature soil on any of the deposits. The more nearly level the deposit, the deeper are the clays. The streams crossing the deposits are rapidly down-cutting, thus very little transported material is found along the banks.

The deposits occur as ridges or outcrops. The olivine is more resistant than the surrounding rocks. It weathers slowly by chemical decomposition. Where seams or veins of vermiculite or anthophyllite occur in the deposit, mechanical weathering takes place. Deposit No. 9 supports a more mesic vegetation on the south slope because the physical weathering of anthophyllite and vermiculite has produced a deeper and better moisture-holding soil. In general, however, erosion on the slopes and rapid leaching of the soluble compounds prevent the accumulation of soil materials.

Very little is known about the formation of soil from olivine, but Merrill (1921) states: "The deep green serpentines of Harford County, Maryland, weather slowly down into a gray-brown soil, which consists of 60.17% silica, 10.40% of the iron oxides, 14.81% of alumina, and only 7.23% magnesia. A fresh rock, on the other hand, carries nearly 40% of magnesia, 8.50% iron and other metallic oxides, and less than one-half of one per cent of alumina."

Ten samples of residual clays from communities on various deposits were tested for acidity and alkalinity. The Beckman pH meter was used in making the tests. 10 grams of air-dried clay were mixed with 25 cc. of distilled water and left overnight in a closed container before testing. The samples taken from the surface clays to a depth of one or two inches were acid, the average pH being 6.3. Two samples taken from the bottom inch above the parent rock were slightly alkaline, pH 7.6 and 7.4.

Judging from the distribution of ericaceous plants, which grow only where the residual clays are 4 or more inches in depth, and from the results of the pH tests, it seems that the surface layers of the deeper clays are acid. Apparently a high percentage of the Mg ions are leached as soon as the olivine goes into solution.

Gordon and Lipman (1930), in a study on why soils derived from basic magnesian rocks in California are infertile, found that the magnesium had no toxic effect on the plants. They concluded that the high pH (about 8.1), and nitrate and phosphate deficiencies were responsible for poor growth. Dr. Lutz, Department of Agriculture, Soils Division, Raleigh, N. C., in unpublished observations said that soils derived from dunite and serpentine are some of our most productive in North Carolina when lime, nitrates, and phosphates are added as fertilizers. A farmer reported to me that his corn yield on Deposit No. 9 was greater than that of a similar acreage of bottom land. He used lime as a fertilizer and planted near the base of the deposit where the clays were six inches deep or deeper. The natural vegetative growth on the deposits is luxuriant where there is abundant moisture.

CLIMATOLOGY

The climate of the mountain region of western North Carolina is a modified continental type. The summers are cooler and the winters are milder than corresponding seasons in the interior states. Valleys and ridges and differences in elevation are responsible for sharp climatic variations in relatively small areas.

The rainfall ranges from 39.13 inches annually at Marshall in the central mountain region, to 82.63 inches at Highlands in the southern mountain region. The January temperature average is approximately 38°F. and the July average is approximately 71°F. for the entire region. The first killing frosts in the fall usually occur the second week of October, and the last killing frost of spring occurs the last week of April.

Although data from weather stations in the mountain region show climatic differences, the vegetation on the deposits appears to be essentially the same throughout the olivine belt.

PLANT COMMUNITIES

General

All of the communities on olivine are characterized by a great number of species but by very few individuals of any single species. I have described seven communities on the deposits and one community on soils derived from rocks surrounding the olivine. These communities are: (1) maple-beech-birch-magnolia; (2) pine-andropogon (grass); (3) pine-oak; (4) oak-grass; (5) oak-shrub; (6) grass-weed (pasture on dunite); (7) alder-sedge-smartweed; and (8) grass-weed-oak (pasture on soils derived from rocks surrounding the olivine deposits).

With the exception of the pine-andropogon (various grasses and small herbs) community which is the most striking one on the deposits, the others are more or less typical of the mountain region. I have not observed a pine (pitch and scrub)-andropogon community above 2000 feet in the Blue Ridge except where pines have been planted for soil conservation purposes. The only large pine communities that I have observed are those composed of white pines in the wetter locations of the mountains.

On the north slopes of the deposits where moisture is more abundant, a maple-beech-birch-magnolia community is found. On the drier south slopes with other edaphic conditions the same as those on the north slopes, a pine-andropogon community is found. If there is more soil material, therefore more moisture, on a south slope, a pine-oak or oak-shrub community is found.

My observations on the controlling factors in distribution of species and communities agree in general with those of Harshberger (1903), who studied the serpentine barrens of Pennsylvania. He states that "one fact is proved abundantly by a study of the flora of the serpentine barrens and that is that the chemical character of the soil derived from the disintegration of serpentine plays an unimportant part in the distribution of the plants mentioned. The distribution of such species is due rather to the physical conditions of the soil especially with reference to water conductivity and water storage conditions. The variation and character of the plant associations described above is in main due to the character of the soil. If the soil is present as a well marked surface layer then tree associations are found, if on the other hand the rock is exposed, herbaceous associations are the rule. The surface layers of serpentine rock are broken by weathering into angular fragments, which lying loosely together, permit the percolation of the rain water down into the seams of the underlying rock. Such exposures therefore, support plants that have adapted themselves to living in dry situations and have structural arrangements which prevent a rapid loss of water." Soil acidity or alkalinity is also a very important factor in species distribution.

All of the deposits have been cut over in the last 60 years and several have been mined. Cane Creek, Holcombe Branch, Frank, and Newfound Gap Deposits are partly seeded pastures at present. Cultivation has left its imprint on the community pattern on Deposit No. 9. The maple-beech-birch-magnolia community on the Day Book Deposit has been destroyed during the past year by highway construction.

The communities found on each of the deposits are as follows: Cane Creek, grass-weed; Corundum Hill, maple-beech-birch-magnolia, pine-andropogon, pine-oak; Day Book, maple-beech-birch-magnolia, pine-andropogon, pine-oak; Dark Ridge, maple-beech-birch-magnolia, pine-andropogon, pine-oak, grass-weed; No. 9, maple-beech-birch-magnolia, oak-grass; Frank, grass-weed, maple-beech-birch-magnolia, alder-sedge-smartweed; Holcombe Branch, pine-andropogon, grass-weed, pine-oak, alder-sedge-smartweed; Laurel Creek, maple-beech-birch-magnolia, pine-oak, pine-andropogon; Newfound Gap, grass-weed.

TABLE III

pH Tests on Residual Clays

COMMUNITY	DEPOSIT	pH
Maple-beech-birch-magnolia	Day Book	7.0
Maple-beech-birch-magnolia	Dark Ridge	6.3
Maple-beech-birch-magnolia	Laurel Creek	7.6
Pine-oak	Holcombe Branch	5.2
Pine-oak	Dark Ridge	5.4
Pine-andropogon	Laurel Creek	6.8
Pine-andropogon	Holcombe Branch	6.65
Pine-andropogon	Day Book	7.4
Grass-weed	Holcombe Branch	6.5
Oak-grass	Deposit No. 9	6.8

Following are the abbreviations of the deposits and the communities, and their meanings as employed in the following pages:

Deposits	*Communities*
CC—Cane Creek	mbm—maple-beech-birch-magnolia
CH—Corundum Hill	og—oak-grass
DB—Day Book	os—oak-shrub
DR—Dark Ridge	pa—pine-andropogon (grass)
D9—No. 9	pas—grass-weed-oak (pasture on surrounding rock or soils derived therefrom)
F—Frank	
HB—Holcombe Branch	
LC—Laurel Creek	pd—grass-weed (pasture on dunite)
N—Newdale	po—pine-oak
NG—Newfound Gap	s—alder-sedge-smartweed

Description of Communities

1) *Maple-beech-birch-magnolia community*

This community which is highly mesophytic is characterized in general by dense vegetation and is particularly well-developed on the northern slopes near the streams. It occurs on the Corundum Hill, Dark Ridge, Day Book, No. 9, Frank, and Laurel Creek Deposits.

On the Corundum Hill Deposit *Fagus grandifolia*, *Acer rubrum*, and *Betula lenta* are the dominant trees. These trees are 4–12 inches in diameter and 20–40 ft. tall. *Cornus florida* and various saplings form a scattered irregular

layer beneath the tree cover. The most common shrubs scattered through the community are *Rhododendron calendulaceum*, *Benzoin aestivale*, *Kalmia latifolia*, and *Hydrangea arborescens*. The herbaceous ground cover consists of a wide variety of species, with the ferns *Osmunda cinnamomea*, *Adiantum pedatum*, *Athyrium thelypteroides*, and *Athyrium asplenioides* being the most common. Some of the other more common herbaceous species are *Cimicifuga racemosa*, *Heuchera americana*, *Luzula campestris* var. *bulbosa*, *Sanicula canadensis*, *Glyceria melicaria*, *Nepeta hederacea*, *Oxalis corniculata*, *Ranunculus recurvatus*, and *Thalictrum dioicum*. *Phlox stolonifera* forms a patch covering nearly 40 sq. ft. near the stream.

On the Dark Ridge Deposit *Acer pennsylvanicum*, *A. rubrum*, *Magnolia acuminata*, and *Betula lenta* are the dominant trees. These are 4–10 inches in diameter, and 25–50 ft. tall. *Calycanthus fertilis*, *C. nanus*, *Evonymus obovatus*, *Pyrularia pubera*, *Hydrangea arborescens*, *Rubus occidentalis*, and *R. odoratus* are the common shrubs. The herbaceous vegetation is the most luxuriant found in any community. *Tiarella cordifolia*, *Thaspium aureum*, *Zizia cordata*, *Disporum lanuginosum*, *Trillium erectum*, *Polystichum acrostichoides*, *Smilacina racemosa*, *Polygonatum biflorum*, *Clintonia umbellulata*, *Arabis canadensis*, *Gentiana quinquefolia*, and *Aster divaricatus* are the more common herbaceous species. *Polypodium virginianum* and several species of mosses form a mat on the olivine boulders. One of these boulders 20 feet above stream level is covered by a patch of *Camptosorus rhizophyllus* about 10 sq. ft. in area.

On the Day Book Deposit *Pinus Strobus*, *Tsuga canadensis*, *Acer rubrum*, and *Liriodendron tulipifera* are the dominant trees. These trees are 4–12 inches in diameter and 20–50 ft. tall. *Kalmia latifolia* and *Rhododendron maximum* form a dense entanglement beneath the *Pinus Strobus* and *Tsuga canadensis*. *Alnus rugosa*, *Benzoin aestivale*, *Pyrularia pubera*, *Cornus alternifolia*, and *Sambucus pubens* are the more common shrubs beneath *Acer rubrum* and *Liriodendron tulipifera*. *Carex pennsylvanica*, *C. digitalis*, *Stellaria pubera*, *Polygonatum commutatum*, *Smilacina racemosa*, and *Trillium erectum* are the more common herbaceous species. *Stenanthium gramineum* forms several large colonies. *Phlox stolonifera* also forms one large colony. Mosses, lichens, and *Polypodium virginianum* form thick carpets on the olivine boulders in this community.

On Deposit No. 9 the maple-beech-birch-magnolia community is drier than on the other deposits. *Fagus grandifolia*, *Quercus falcata*, *Q. alba*, and *Q. coccinea* are the dominant trees. These are 4–15 inches in diameter and 20–50 ft. tall. *Cornus florida*, *Sassafras albidum*, and numerous other saplings form an irregular layer beneath the tree cover. The common shrubs are *Vaccinium stamineum*, *Hydrangea arborescens*, and *Corylus americana*. *Adiantum pedatum*, *Carex rosea*, *Circaea latifolia*, *Podophyllum peltatum*, *Sabatia angularis*, *Sanicula canadensis*, and *Scutellaria incana* are the common herbaceous species. *Frasera caroliniensis* forms a large colony in the cove at the western end of the deposit.

On the Frank Deposit this community is approximately 100 feet above the stream level. *Acer rubrum*, *Quercus borealis* var. *maxima*, *Betula lenta*, *Fagus grandifolia*, and *Magnolia acuminata* are the dominant trees. These trees are

6–15 inches in diameter and 30–60 ft. tall. *Rhododendron maximum* and *Kalmia latifolia* form dense entanglements in parts of the community. *Clethra acuminata*, *Hydrangea arborescens*, and *Rhododendron calendulaceum* are the common shrubs. *Adiantum pedatum*, *Aster divaricatus*, *Cystopteris fragilis*, *Polystichum acrostichoides*, *Carex varia*, *Silene stellata*, and *Iris cristata* are the common herbs. *Camptosorus rhizophyllus* forms small patches of a square foot on several of the olivine boulders. Mosses and lichens form thin mats or carpets on other boulders in this community.

On the Laurel Creek Deposit *Pinus Strobus* and *Tsuga canadensis* are the dominant trees along the streams, and a little higher on the slopes where there is less moisture, *Acer rubrum* and *Fagus grandifolia* are dominant. These trees are 6–15 inches in diameter and 20–50 ft. tall. *Rhododendron maximum* and *Kalmia latifolia* are the common shrubs beneath *Pinus Strobus* and *Tsuga canadensis*. *Gaylussacia ursina*, *Hydrangea arborescens*, *H. cinerea*, and *Asimina triloba* are the more common shrubs beneath *Acer rubrum* and *Fagus grandifolia*. *Sanicula canadensis*, *Mitchella repens*, *Collinsonia canadensis*, *Tiarella cordifolia*, *Mitella diphylla*, *Thaspium aureum*, and *Asarum grandiflorum* are the common herbaceous species. *Conopholis americana* forms a 40 square foot patch in the central cove.

2) *Pine-andropogon community*

This xerophytic community is characterized by an open stand of pines which are mostly 20–30 feet apart, with a grass-herbaceous ground cover through which are scattered low shrubs. This type of community is found on the dry southern slopes of the Corundum Hill, Day Book, Holcombe Branch, and Laurel Creek Deposits.

On the Corundum Hill Deposit *Pinus rigida* and *P. virginiana* are the dominant trees. *Quercus falcata* and *Q. stellata* are the sub-dominants. The pines are 9–20 inches in diameter and 30–40 ft. tall. At least one fourth of the pines are forked at the base. The oaks are 2–6 inches in diameter and seldom over 20 ft. tall. Along the mine veins are found *Acer rubrum*, and *Liriodendron tulipifera* saplings which have yellowish leaves and appear dwarfed. *Gaylussacia baccata*, *Vaccinium stamineum*, *Physocarpus opulifolius*, *Kalmia latifolia*, and *Rhododendron maximum* are the characteristic shrubs. *Alnus rugosa* occurs along the mine veins. *Andropogon furcatus*, *Panicum sphaerocarpon*, *Panicum lanuginosum* var. *fasciculatum*, *Gaultheria procumbens*, *Liatris spicata*, *Hypoxis hirsuta*, *Eryngium aquaticum*, *Lespedeza hirta*, *Hieracium venosum*, *Thalictrum revolutum*, *Sisyrinchium angustifolium*, and *S. mucronatum* are the characteristic herbs.

On the Day Book Deposit *Pinus rigida* is the dominant tree. *Quercus alba*, *Q. stellata*, and *Q. borealis* var. *maxima* are sub-dominants. The pines are 6–8 inches in diameter and 30–40 ft. tall; most of the trunks are crooked. The two specimens of *Quercus stellata* are 15 inches in diameter and 30 ft. tall. *Pinus Strobus* is sparsely intermingled with *P. rigida*. *Betula lenta* growing in this community is stunted, while *Magnolia acuminata* seems to be normal. *Ceanothus*

americanus, *Vaccinium stamineum*, *Rhododendron calendulaceum*, *Kalmia latifolia*, and *Rhododendron maximum* are the common shrubs scattered through the community. *Panicum Boscii*, *P. Ashei*, *P. lanuginosum* var. *fasciculatum*, *Andropogon scoparius*, *Solidago nemoralis*, *Thalictrum revolutum*, *Asclepias verticillata*, *Lespedeza hirta*, *Lobelia inflata*, *Anychia polygonoides*, *Desmodium rigidum*, *D. marilandicum* and *Aster patens* are the common herbaceous species.

On the Holcombe Branch Deposit *Pinus rigida* is the dominant tree in the pine-andropogon community. *Quercus falcata* and *Q. stellata* are sub-dominants. These trees are 6–10 inches in diameter and 20–40 ft. tall. *Ceanothus americanus*, *Lyonia ligustrina* var. *foliosiflora*, *Vaccinium stamineum*, and *Kalmia latifolia* are the common shrubs present. *Andropogon scoparius*, *Panicum sphaerocarpon*, *Scleria ciliata*, *Sericocarpus asteroides*, *Solidago nemoralis*, and *Thalictrum revolutum* are the common herbaceous species. Lichens are abundant on the olivine boulders and on the trees in the community.

On the Laurel Creek Deposit *Pinus virginiana* and *Quercus stellata* are the dominants. The pines are 2–8 inches in diameter and 15–25 ft. tall; the oaks are 4–8 inches in diameter and 10–40 ft. tall. *Ceanothus americanus* and *Kalmia latifolia* are the common shrubs. *Andropogon furcatus*, *Panicum commutatum*, *P. lanuginosum* var. *fasciculatum*, *P. dichotomum*, *Stipa avenacea*, *Melica mutica*, *Asclepias verticillata*, *Sericocarpus asteroides*, *Chrysopsis mariana*, *C. graminifolia*, *Liatris graminifolia*, and *Sisyrinchium angustifolium* are the common herbaceous species.

3) *Pine-oak community*

This is a transition community between the pine-andropogon and the maple-beech-birch-magnolia communities. Pines and oaks predominate, but in general the species composition is mixed. This community occurs on the Dark Ridge, Day Book, Holcombe Branch, and Laurel Creek Deposits.

On the Dark Ridge Deposit, the plants in this community grow mostly in the joints between large olivine boulders. *Pinus rigida*, *P. virginiana*, *Quercus stellata*, *Q. borealis* var. *maxima*, *Q. alba*, and *Q. montana* are the dominant trees. The pines are 6–10 inches in diameter and 20–40 ft. tall. The oaks are 8–12 inches in diameter and 30–50 ft. tall. The shrubs form an almost impenetrable thicket. The shrubs are *Ceanothus americanus*, *Kalmia latifolia*, *Calycanthus fertilis*, *C. nanus*, *Pyrularia pubera*, *Vaccinium stamineum*, *Rhododendron calendulaceum*, woven together by *Smilax glauca*, *S. rotundifolia* var. *quadrangularis*, *Rubus allegheniensis*, and *R. occidentalis*. In the few clearings in the shrub thicket are *Aletris farinosa*, *Gerardia tenuifolia*, *Panicum lanuginosum* var. *fasciculatum*, *Polygala Senega*, *Phlox carolina*, *Galax aphylla*, *Tradescantia montana* var. *subaspera*, *Euphorbia corollata*, and *Coreopsis major*. Very few lichens are found on the olivine boulders of this community.

On the Day Book Deposit *Pinus Strobus*, *Quercus alba*, *Q. borealis* var. *maxima*, *Q. coccinea*, *Q. falcata*, *Q. stellata*, *Oxydendrum arboreum*, and *Nyssa sylvatica* are the dominant trees. These are 6–18 inches in diameter and 20–70 ft. tall. *Rhododendron maximum*, *Ceanothus americanus*, *Vaccinium stamineum*, *Lyonia*

ligustrina, *Sassafras albidum*, and *Rhododendron calendulaceum* are the common shrubs. The more common herbs are *Chrysopsis mariana*, *Coreopsis major*, *Hypericum punctatum*, *Lespedeza hirta*, *Panicum Boscii* var. *molle*, *Pteridium aquilinum* var. *latiusculum*, *Thalictrum revolutum*, *Euphorbia corollata*, and *Aster patens*. Lichens are abundant on the few exposed olivine boulders of this community.

In the pine-oak community on the Holcombe Branch Deposit, *Pinus rigida*, *Quercus stellata*, *Q. falcata* are the dominant trees. These are 3–20 inches in diameter and 10–60 ft. tall, averaging nearly 30 ft. tall. *Castanea pumila*, *Kalmia latifolia*, *Gaylussacia baccata*, *Ceanothus americanus*, *Vaccinium stamineum*, and *Viburnum prunifolium* are the more common shrubs scattered through the community. The common herbaceous species are *Panicum dichotomum*, *P. Boscii* var. *molle*, *Hypericum punctatum*, *Sericocarpus asteroides*, *Thalictrum revolutum*, *Stylosanthes riparia*, *Pteridium aquilinum* var. *latiusculum*, *Chrysopsis mariana*, *Chimaphila maculata*, *Solidago Boottii*, *Sanicula canadensis*, and *Erigeron canadensis*. A few lichens and mosses are found on the olivine boulders.

On the Laurel Creek Deposit *Pinus virginiana*, *Quercus stellata*, *Q. borealis* var. *maxima*, *Nyssa sylvatica*, and *Acer rubrum* are the dominant trees. They are 6–8 inches in diameter and 15 to 30 ft. tall. Several of the trees are stunted and gnarled. *Ceanothus americanus*, *Vaccinium stamineum*, *Lyonia ligustrina*, *Kalmia latifolia*, *Smilax glauca*, and *Vitis rotundifolia* are the common shrubs. *Vitis rotundifolia* forms an extensive ground cover on the northern slope of the deposit. Ferns and grasses compose a large percentage of the herbaceous species. The more common ferns are *Cheilanthes lanosa*, *Polypodium polypodioides*, *Polystichum acrostichoides*, *Asplenium platyneuron*, *A. Trichomanes*, and *Osmunda regalis* var. *spectabilis*. *Melica mutica*, *Stipa avenacea*, *Danthonia sericea*, *Panicum dichotomum*, *P. depauperatum*, and *P. Boscii* are the common grasses. Other common herbs are *Sericocarpus asteroides*, *Sisyrinchium gramineum*, *S. mucronatum*, *Euphorbia corollata*, *Scleria oligantha*, and *Silene virginica*. Lichens are abundant on the boulders.

4) *Oak-grass community*

This community is characterized by a few scattered oaks and a grass-weed ground cover. It is best developed on the south slopes where the soil material is deeper than that found in the pine-andropogon community. The oak-grass community is found on the No. 9 and on the Newdale Deposits.

On the No. 9 Deposit *Quercus imbricaria* is the dominant tree. *Q. stellata*, *Q. alba*, and *Q. falcata* are the sub-dominant trees. The oaks are 6 inches to 2 feet in diameter and up to 30 ft. tall. Most of them have gnarled branches, and some of them have many dead branches in the tops. *Ceanothus americanus*, *Vaccinium stamineum*, *Kalmia latifolia*, *Smilax glauca*, and *S. rotundifolia* var. *quadrangularis* are the common shrubs scattered through the community. *Panicum lanuginosum* var. *fasciculatum*, *P. Boscii* var. *molle*, *P. sphaerocarpon*, *P. dichotomum*, *Thalictrum revolutum*, *Asclepias verticillata*, *Anychia polygonoides*, *Lysimachia quadrifolia*, *Lespedeza hirta*, *Danthonia spicata*, *Scleria ciliata*,

Sisyrinchium gramineum, *Euphorbia corollata*, *Verbascum Thapsus*, and *Silene antirrhina* are the common herbaceous species.

The oak-grass community on the south slope of the Newdale Deposit has a large barren rock outcrop with a few weeds in the small joints between the rocks. The trees are confined to the region around the barren area and to the larger joints between the rocks. *Quercus stellata* and *Q. borealis* var. *maxima* are the dominant trees. These oaks are 6–15 inches in diameter and 30–40 ft. tall. On the more northerly exposures a few plants of *Acer rubrum* and *Betula lenta* are growing. *Kalmia latifolia*, *Corylus americana*, *Crataegus macrosperma*, *Rhododendron calendulaceum*, and *Smilax rotundifolia* var. *quadrangularis* are the common shrubs. The common herbaceous species are *Verbascum Thapsus*, *Veronica officinalis*, *Ambrosia elatior*, *Achillea Millefolium*, *Cirsium lanceolatum*, *Panicum lanuginosum* var. *fasciculatum*, *Digitaria sanguinalis*, *Holcus lanatus*, *Asclepias verticillata*, and *Thalictrum revolutum*.

5) *Oak-shrub community*

This community is characterized by scattered oaks with dense undergrowth of mostly ericaceous shrubs. It is found on the drier slopes where there is an abundance of soil materials, on the Corundum Hill and Newdale Deposits.

On the Corundum Hill Deposit *Quercus stellata*, *Q. borealis* var. *maxima* and *Oxydendrum arboreum* are the dominant trees. These are 2–6 inches in diameter and 10–20 ft. tall. *Gaylussacia baccata*, *Vaccinium stamineum*, and *Smilax glauca* are the common shrubs. The common herbaceous species are *Panicum lanuginosum* var. *fasciculatum*, *Sisyrinchium mucronatum*, *Hypericum punctatum*, and *Pteridium aquilinum* var. *latiusculum*.

On the Newdale Deposit the dominant trees are *Quercus alba*, *Q. stellata*, and *Q. borealis* var. *maxima*. The oaks are 6–10 inches in diameter and 20–40 ft. tall. *Kalmia latifolia*, *Rhododendron maximum*, *Ceanothus americanus*, *Gaylussacia baccata*, and *Smilax glauca* form a very dense entanglement of shrubs beneath the oaks. In the few open areas between the shrubs are *Panicum lanuginosum* var. *fasciculatum*, *P. sphaerocarpon*, *Hypericum punctatum*, *Hieracium Gronovii*, *Anychia polygonoides*, *Desmodium rhombifolium*, and *Rumex Acetosella*. Most of the olivine boulders in this community are covered with lichens and mosses.

6) *Grass-weed community* (Pasture on dunite)

This community is composed of native and cultivated grasses, weeds, and a few scattered trees and shrubs. It occurs on Cane Creek, Dark Ridge, Frank, Holcombe Branch, and Newfound Gap Deposits.

The Cane Creek pasture is on a steep slope. There are many olivine boulders in the community with a few grasses and herbs in the crevices between the boulders. *Pinus rigida* and *Crataegus Crus-galli* are scattered throughout the pasture. The pines are 4–6 inches in diameter and 10–15 ft. tall. The dominant herbaceous species are *Agrostis perennans*, *A. hiemalis*, *Paspalum laeve*, *Panicum lanuginosum* var. *fasciculatum*, *Trifolium procumbens*, and *T. repens*. The other

common herbs are *Chrysanthemum Leucanthemum, Achillea Millefolium, Plantago lanceolata, P. virginica, Erigeron canadensis, Rumex Acetosella,* and *Hedeoma Pulegioides.*

On the Dark Ridge Deposit the grass and herbaceous growth is luxuriant along the streams but poor on the drier areas. Along the railroad tracks through the middle of the pasture, are found *Cornus alternifolia, Sassafras albidum, Aesculus octandra, Hydrangea arborescens, Amelanchier canadensis, Thuja occidentalis* var. *pyramidalis,* and *Rhododendron calendulaceum.* In the upper end of the pasture is a colony of *Halesia carolina* saplings. *Juglans cinerea,* 12 inches in diameter and 30 feet tall, and *Crataegus Crus-galli* grow in the lower end of the pasture. The herbaceous species are numerous. The ferns *Asplenium platyneuron, A. Trichomanes, Adiantum pedatum, Athyrium asplenioides, Osmunda cinnamonea, O. regalis* var. *spectabilis, O. Claytoniana, Polystichum acrostichoides,* and *Dennstaedtia punctilobula* are very common. Some of the other more common herbaceous species are *Epilobium coloratum, Achillea Millefolium, Aster divaricatus, Barbarea vulgaris, Anthoxanthum odoratum, Cerastium viscosum, Chrysanthemum Leucanthemum, Cirsium lanceolatum, Clematis Viorna, Danthonia spicata, Daucus Carota, Digitaria sanguinalis, Diodia teres, Eleusine indica, Erigeron annuus, E. ramosus, Sisymbrium officinale, Eupatorium urticaefolium, Galinsoga ciliata, Gaura biennis, Gnaphalium obtusifolium, G. purpureum, Hedeoma pulegioides, Juncus tenuis, Lobelia siphilitica, Lysimachia quadrifolia, Oxalis stricta, Plantago lanceolata, Phleum pratense, Prunella vulgaris, Ranunculus recurvatus, R. repens, Rumex Acetosella, Salvia lyrata, Sanicula canadensis, Silene virginica, Specularia perfoliata, Trifolium repens, Poa compressa,* and *Verbascum Thapsus.*

The pasture on the Frank Deposit occurs on very steep slopes. The western slope is the most barren area found on any of the deposits. The broad-leaved vegetation appears dwarfed and stunted. A few saplings of *Acer rubrum, Aesculus octandra, Betula lenta,* and *Robinia Pseudo-Acacia* are scattered throughout the community. A few specimens of the following shrubs are found in the pasture: *Kalmia latifolia, Spiraea alba, Rhododendron maximum, R. calendulaceum, Crataegus collina, C. Crus-galli, Alnus rugosa, Smilax glauca,* and *S. rotundifolia* var. *quadrangularis.* The common herbaceous species are *Adiantum pedatum, Aquilegia canadensis, Achillea Millefolium, Agrostis alba, A. hiemalis, Anychia polygonoides, Arenaria serpyllifolia, Asclepias verticillata, Silene virginica, Dianthus Armeria, Eupatorium urticaefolium, Gnaphalium obtusifolium, Lepidium virginicum, Lobelia inflata, Sorghastrum nutans, Verbascum Blattaria, V. Thapsus,* and *Veronica officinalis.*

The pasture on the Holcombe Branch Deposit is the only one cut for hay and is reseeded frequently. A small part of this pasture is fenced and grazed. Very few large boulders are found in the entire pasture, which is located on gentle slopes. A few trees, *Acer rubrum, Prunus virginiana, Oxydendrum arboreum, Cornus florida, Juglans nigra, Pinus Strobus, Crataegus macrosperma,* and *C. Crus-galli* occur in the pasture. The trees are 6–12 inches in diameter, 15–50 ft. tall. The dominant herbs are *Agrostis alba, Holcus lanatus, Phleum pratense, Bromus commutatus, Trifolium repens, Achillea Millefolium, Dactylis glomerata,*

Ambrosia elatior, *Chrysanthemum Leucanthemum*, *Poa compressa*, *Erigeron annuus*, *Lepidium virginicum*, *Plantago lanceolata*, *Rumex Acetosella*, and *Veronica officinalis*.

The upper third of the pasture on the Newfound Gap Deposit is wooded by oaks; the center third is devoid of trees, and the lower third is wooded by black locusts. The common trees are *Quercus borealis* var. *maxima*, *Q. alba*, *Q. montana*, *Q. velutina*, *Q. coccinea*, *Robinia Pseudo-Acacia*, *Carya glabra*, and *Pinus virginiana*. The oaks are 9–15 inches in diameter, and 30–50 ft. tall. The black locusts are 12 inches in diameter and 50–60 ft. tall. Most of the latter are dead or dying. *Ceanothus americanus*, *Hydrangea arborescens*, *Rubus argutus*, and *Rubus allegheniensis* are the common shrubs. A large colony of *Rhus glabra* covers an area about 30 feet wide and 75 feet long beneath the power lines near the top of the deposit. These shrubs are about 8 feet tall. The more common herbaceous species are *Gerardia tenuifolia*, *Agrostis perennans*, *Dactylis glomerata*, *Danthonia spicata*, *Muhlenbergia Schreberi*, *Panicum commutatum*, *P. dichotomum*, *Phleum pratense*, *Pteridium aquilinum* var. *latiusculum*, *Rumex Acetosella*, *Sphenopholis obtusata*, *Carex rosea*, *Sisyrinchium gramineum*, *Rudbeckia hirta*, and *Silene virginica*. *Senecio aureus* forms a large ground cover in the center third of the community. *Nepeta hederacea* makes a carpet beneath the black locusts on the lower third. Lichens are abundant on the trees and rocks in this community.

7) *Alder-sedge-smartweed community*

This community is found along the banks of streams that cross the deposits. It occurs on the Frank, Holcombe Branch, and Newdale Deposits.

On the Frank Deposit several saplings of *Platanus occidentalis* and *Populus candicans* are scattered along the stream. *Alnus rugosa* is the most common shrub. *Sambucus canadensis*, *Salix sericea*, *S. nigra*, *Rosa palustris*, and *Symphoricarpos orbiculatus* are the other less common shrubs. The common herbaceous species are *Carex lurida*, *C. vulpinoidea*, *Leersia oryzoides*, *Juncus effusus*, *J. marginatus*, *Eleocharis obtusa*, *Polygonum Hydropiper*, *P. pennsylvanicum*, *P. sagittatum*, *Scirpus sylvaticus*, *Solidago canadensis*, *Equisetum arvense*, *Ranunculus acris*, *Lycopus uniflorus*, *Helenium autumnale*, *Oenothera biennis*, *Mentha piperita*, *Mimulus ringens*, *Lysimachia Nummularia*, and *Myosotis laxa*.

On the Holcombe Branch Deposit, several saplings of *Platanus occidentalis* are found along the stream. The common shrubs are *Alnus rugosa*, *Benzoin aestivale*, *Sambucus canadensis*, *S. pubens*, *Salix sericea*, *S. nigra*, *Rosa carolina*, *Rubus allegheniensis*, *R. occidentalis*, *Vitis bicolor*, *V. cordifolia*, and *V. labrusca*. *Carex lurida*, *C. vulpinoidea*, *Glyceria striata*, *Leersia oryzoides*, *Juncus tenuis*, *J. effusus*, *Hypericum mutilum*, *Helenium autumnale*, *Eleocharis obtusa*, *Apios tuberosa*, *Ludvigia palustris*, *Lysimachia Nummularia*, *Mentha piperita*, *Lycopus virginicus*, *Onoclea sensibilis*, *Scirpus atrovirens*, *S. sylvaticus*, *Solidago canadensis*, *Polygonum hydropiperoides*, *P. pennsylvanicum*, *P. virginianum*, *Rudbeckia laciniata*, *Eupatorium purpureum*, *E. perfoliatum*, *Cryptotaenia canadensis*, *Echinochloa crus-galli*, *Cicuta maculata*, *Aster paniculatus*, *Lactuca spicata*, and *L. villosa* are the common herbaceous species on this deposit, in the alder-sedge-smartweed community.

Saplings of *Betula lenta*, *Carpinus caroliniana*, *Liriodendron tulipifera*, and *Prunus virginiana* occur along the stream on the Newdale Deposit. The common shrubs are *Alnus rugosa*, *Rhododendron calendulaceum*, *Kalmia latifolia*, and *Sassafras albidum*. *Carex scoparia*, *C. debilis*, *C. lurida*, *C. vulpinoidea*, *Cyperus strigosus*, *Helenium autumnale*, *Juncus effusus*, *J. tenuis*, *Lobelia cardinalis*, *Lycopus virginicus*, *Muhlenbergia Schreberi*, *Panicum clandestinum*, *Polygonum pennsylvanicum*, *P. Persicaria*, *P. punctatum*, *P. sagittatum*, *Scirpus atrovirens*, *S. validus*, and *Cardamine pennsylvanica*, are the common herbaceous species.

8) *Grass-weed-oak community* (Pasture on soils derived from rocks surrounding the olivine deposits).

This community is developed on soils derived from gneiss, biotite schist, and quartz surrounding the olivine deposits. The vegetation is composed predominantly of grass and herbaceous weeds, but in general more trees and shrubs are found in this community than in the grass-weed community on dunite. The pastures surrounding the Cane Creek and Newfound Gap Deposits were studied.

Pinus rigida, *P. echinata*, *Quercus alba*, *Q. montana*, *Q. falcata*, and *Q. stellata* are the common trees found in the community surrounding Cane Creek. These trees are 4–8 inches in diameter and 15–30 ft. tall. The more common shrubs are *Sambucus canadensis*, *Rhododendron calendulaceum*, *Benzoin aestivale*, *Calycanthus nanus*, *Rhus copallina*, and *Hydrangea arborescens*. *Agrostis perennans*, *Dactylis glomerata*, *Panicum dichotomum*, *Paspalum laeve*, *Hedeoma pulegioides*, *Gnaphalium obtusifolium*, *Cassia nictitans*, *Erigeron annuus*, *E. pulchellus*, *Polystichum acrostichoides*, *Rumex Acetosella*, *Trifolium pratense*, *T. procumbens*, *T. repens*, *T. agrarium*, *Plantago lanceolata*, *Antennaria plantaginifolia*, and *Krigia virginica* are the common herbaceous species.

In the community surrounding the Newfound Gap Deposit, *Quercus alba*, *Q. montana*, *Pinus virginiana*, *Acer rubrum*, and *Carya glabra* are the dominant trees. These are 6–12 inches in diameter and 20–50 ft. tall. The common shrubs are *Castanea pumila*, *Benzoin aestivale*, *Hydrangea arborescens*, *Amorpha fruticosa*, and *Rhododendron calendulaceum*. *Agrostis alba*, *Panicum lanuginosum* var. *fasciculatum*, *Achillea Millefolium*, *Poa compressa*, *Danthonia spicata*, *Trifolium repens*, *Veronica arvensis*, *Prunella vulgaris*, *Nepeta hederacea*, *Holcus lanatus*, *Hypoxis hirsuta*, *Juncus tenuis*, *Plantago aristata*, *Pteridium aquilinum* var. *latiusculum*, *Specularia perfoliata*, *Solanum carolinense*, and *Erigeron pulchellus* are the common herbs.

FLORISTICS

General

The vascular flora on the ten deposits is represented by 750 species and varieties. The maximum number on any single deposit is 344, on the Dark Ridge Deposit. The minimum number is 162, on the Cane Creek Deposit. The maximum number in any one community is 454, in the maple-beech-birch-magnolia community. The minimum, 106, is in the oak-shrub community. A total of 3475 specimens was collected on the ten deposits during this study.

The vascular flora consists of 712 angiosperms (537 dicotyledons and 175 monocotyledons), 8 gymnosperms, and 30 pteridophytes. The trees are represented by 74 species, the shrubs by 53 species, the woody vines by 11, and the herbs by 612. For the number of species on each deposit and in each community, see Table IV.

The following species and varieties are found on all ten deposits: *Asplenium platyneuron*, *Polystichum acrostichoides*, *Smilax rotundifolia* var. *quadrangularis*,

TABLE IV

Species Summary

DEPOSITS	CC	CH	DB	DR	D9	F	HB	LC	N	NG	TOTAL
Vascular Plants	162	233	233	344	182	219	249	199	195	177	750
Pteridophytes	9	14	12	19	11	13	6	14	6	8	30
Gymnosperms	3	1	4	3	3	1	4	3	1	2	8
Angiosperms	150	218	217	322	168	205	239	182	188	167	712
Monocotyledons	33	58	55	63	32	53	43	40	48	29	175
Dicotyledons	117	160	162	259	136	152	196	142	140	138	537
Trees	25	23	28	35	25	20	32	24	22	21	74
Shrubs	13	30	19	31	16	17	25	25	16	16	53
Woody Vines	1	3	6	4	1	1	5	1	2	2	11
Herbs	121	177	180	274	140	181	187	149	155	138	612

COMMUNITIES	mbm	og	os	pa	pas	pd	po	s	TOTAL
Vascular Plants	454	181	106	171	176	351	248	229	750
Pteridophytes	25	9	7	9	9	17	16	7	30
Gymnosperms	3	4	1	3	4	6	4	1	8
Angiosperms	426	168	98	159	163	334	228	221	715
Monocotyledons	108	31	26	39	31	62	51	53	175
Dicotyledons	318	137	72	120	132	272	177	168	537
Trees	46	26	15	21	27	43	36	20	74
Shrubs	38	17	19	27	15	24	25	17	53
Woody Vines	7	1	1	1	2	6	5	4	11
Herbs	363	137	71	122	132	284	182	188	612

Rubus argutus, *Hypericum punctatum*, *Kalmia latifolia*, *Rhododendron calendulaceum*, and *Erigeron ramosus*. Following are those found on nine of the deposits: *Adiantum pedatum*, *Panicum dichotomum*, *P. lanuginosum* var. *fasciculatum*, *Poa compressa*, *Smilax glauca*, *Phytolacca americana*, *Cerastium viscosum*, *Silene virginica*, *Liriodendron tulipifera*, *Sassafras albidum*, *Amphicarpa monoica*, *Acer rubrum*, *Ceanothus americanus*, *Sanicula canadensis*, *Solanum carolinense*, *Verbascum Thapsus*, *Plantago lanceolata*, *Chrysanthemum Leucanthemum*, and *Erigeron pulchellus*.

The maple-beech-birch-magnolia community occurs on six of the deposits. *Kalmia latifolia* and *Erigeron ramosus* are found in this community on all six.

The following species are found in this community on five of the deposits: *Adiantum pedatum*, *Polystichum acrostichoides*, *Chamaelirium luteum*, *Hydrangea arborescens*, *Acer rubrum*, *Lysimachia quadrifolia*, and *Eupatorium urticaefolium*.

The pine-andropogon community is found on four deposits. Plants found on all four are: *Quercus stellata*, *Lespedeza hirta*, *Ceanothus americanus*, *Hypericum punctatum*, *Chimaphila maculata*, *Kalmia latifolia*, and *Coreopsis major*. The following species are found in the pine-andropogon community on three of the deposits: *Pinus rigida*, *Panicum dichotomum*, *Lilium carolinianum*, *Thalictrum revolutum*, *Sassafras albidum*, *Robinia Pseudo-Acacia*, *Oxydendrum arboreum*, *Chrysopsis mariana*, *Erigeron ramosus*, *Hieracium venosum*, and *Sericocarpus asteroides*.

The pine-oak community occurs on four of the deposits. The following species are found on all four: *Asplenium platyneuron*, *Quercus borealis* var. *maxima*, *Kalmia latifolia*, and *Rhododendron calendulaceum*. The following species are found in this community on three of the deposits: *Polystichum acrostichoides*, *Pteridium aquilinum* var. *latiusculum*, *Pinus Strobus*, *P. virginiana*, *Iris cristata*, *Quercus stellata*, *Thalictrum revolutum*, *Euphorbia corollata*, *Acer rubrum*, *Ceanothus americanus*, *Lyonia ligustrina*, *Oxydendrum arboreum*, *Vaccinium pallidum*, and *Solanum carolinense*.

The oak-grass community is found on two of the deposits. The following plants occur in this community on both of the deposits: *Adiantum pedatum*, *Asplenium platyneuron*, *Polystichum acrostichoides*, *Panicum dichotomum*, *P. sphaerocarpon*, *Smilax rotundifolia* var. *quadrangularis*, *Quercus alba*, *Q. stellata*, *Phytolacca americana*, *Anemone virginiana*, *Thalictrum revolutum*, *Sassafras albidum*, *Platanus occidentalis*, *Rubus argutus*, *Robinia Pseudo-Acacia*, *Acer rubrum*, *Hypericum punctatum*, *Psedera quinquefolia* var. *hirsuta*, *Sanicula canadensis*, *Cornus alternifolia*, *Kalmia latifolia*, *Asclepias verticillata*, *Solanum carolinense*, *Verbascum Thapsus*, *Specularia perfoliata*, *Erigeron ramosus*, *Eupatorium aromaticum*, *Gnaphalium obtusifolium*, and *Solidago nemoralis*.

The oak-shrub community is found on two of the deposits. The following species are found in this community on both deposits: *Fagus grandifolia*, *Quercus stellata*, *Rubus argutus*, *R. occidentalis*, *Ceanothus americanus*, *Hypericum punctatum*, *Sanicula canadensis*, *Nyssa sylvatica*, *Kalmia latifolia*, *Rhododendron calendulaceum*, *Scutellaria pilosa*, *Galium circaezans*, *Houstonia purpurea*, and *Aster divaricatus*.

The grass-weed community is found on five deposits. *Panicum lanuginosum* var. *fasciculatum*, *Poa compressa*, and *Erigeron ramosus* are found on all five deposits. The following species are found in this community on four of the deposits: *Smilax glauca*, *S. rotundifolia* var. *quadrangularis*, *Rumex Acetosella*, *Phytolacca americana*, *Silene virginica*, *Lepidium virginicum*, *Rubus argutus*, *Robinia Pseudo-Acacia*, *Trifolium repens*, *Acer rubrum*, *Hypericum punctatum*, *Cornus florida*, *Kalmia latifolia*, *Rhododendron maximum*, *Verbascum Thapsus*, *Veronica officinalis*, *Plantago lanceolata*, *Specularia perfoliata*, *Achillea Millefolium*, *Gnaphalium purpureum*, and *Senecio Smallii*.

The alder-sedge-smartweed community is found on three of the deposits.

Species found on all three are: *Echinochloa crus-galli, Holcus lanatus, Carex lurida, C. vulpinoidea, Cyperus strigosus, Scirpus atrovirens, Juncus effusus, Salix nigra, Alnus rugosa, Polygonum pennsylvanicum, P. sagittatum, Rubus argutus, Lycopus virginicus, Achillea Millefolium, Ambrosia elatior, Chrysanthemum Leucanthemum, Erigeron ramosus, Helenium autumnale,* and *Vernonia noveboracensis.*

The grass-weed-oak communities around two deposits were studied. Following are the species found in both: *Asplenium platyneuron, Athyrium thelypteroides, Polystichum acrostichoides, Pteridium aquilinum* var. *latiusculum, Juniperus virginiana, Panicum lanuginosum* var. *fasciculatum, Poa compressa, Arisaema atrorubens* forma *viride, Juncus tenuis, Carya glabra* var. *villosa, Quercus alba, Q. montana, Q. velutina, Polygonum Persicaria, Rumex Acetosella, R. obtusifolius, Phytolacca americana, Cerastium vulgatum, Ranunculus recurvatus, Benzoin aestivale, Lepidium virginicum, Hydrangea arborescens, Potentilla canadensis, Rubus argutus, Trifolium repens, Hypericum punctatum, Sanicula canadensis, Rhododendron calendulaceum, Solanum carolinense, Verbascum Thapsus, Plantago lanceolata, Houstonia purpurea, Specularia perfoliata, Erigeron pulchellus, E. ramosus, Gnaphalium purpurem,* and *Senecio Smallii.*

Endemism

Mason (1946), in discussing the reasons for endemism in California states: "It is obvious that the Napa-Lake area owes its high concentration of endemics to its great edaphic diversity and especially to the fact that this diversity involves peculiar rocks and their associated minerals. Next in order of importance is the presence in the area of a number of genera capable of elaboration over these peculiar habitats. Those genera which give rise to an occasional endemic species are not responsible for the large number of endemics. It is, on the other hand, such genera as *Navarretia, Linum,* and *Streptanthus* which develop many local species and habitat races, that build up the population of restricted endemics in a small area and that give the impression of some sort of genetic instability. It becomes clear that diversity in the environment must work with genetic diversity and must involve diverse tolerances, to produce situations such as that in the Napa-Lake area or in any rich flora." Fernald (1907), in his study of the soil preferences of alpine plants, found 21 species strictly localized on the serpentine of Mt. Albert, Gaspé County, Quebec. I have found none of those species on the North Carolina or Georgia deposits. Pennell (1910) found 17 species restricted to the Conowingo Barrens (serpentine) in southeastern Pennsylvania. Of those 17 species, *Sphenopholis obtusata* and *Asclepias verticillata* are found on the olivine deposits I have studied.

I have not found any species that I consider endemic to the olivine deposits in North Carolina or Georgia on which I have collected extensively. Several species that are localized on the deposits are not found in the immediate areas surrounding the deposits, but do occur elsewhere in the state. These species are as follows: *Quercus stellata, Pinus rigida, Thalictrum revolutum, Asclepias verticillata, Physocarpus opulifolius, Danthonia spicata, Andropogon scoparius, A.*

furcatus, Cystopteris fragilis, Camptosorus rhizophyllus, Carex plantaginea, C. leptalea, C. heterosperma, Cyperus filiculmis var. *macilentus, Scleria ciliata, S. oligantha, Aletris farinosa, Sisyrinchium gramineum, S. mucronatum, S. angustifolium, Arenaria serpyllifolia, A. patula, Lespedeza hirta, Polygala Senega, Liatris graminifolia, L. spicata, Clematis Beadlei, Ruellia humilis, Eupatorium latidens,* and *Frasera caroliniensis.*

Range Extensions

Arenaria patula Muhl., *Ruellia humilis* Nutt., and *Eupatorium latidens* Small are reported as new to North Carolina. *Clematis Beadlei* (Small) Erickson is reported as new to Georgia.

New county locations for the following ferns in North Carolina are:

Jackson County—*Polypodium polypodioides*
Avery County—*Camptosorus rhizophyllus*
Osmunda cinnamomea
Yancey County—*Adiantum pedatum*
Asplenium Trichomanes
Athyrium thelypteroides
Dennstaedtia punctilobula
Dryopteris marginalis
Onoclea sensibilis
Polystichum acrostichoides var. *incisum*

Plants of Interest

Plants found on the olivine deposits that normally grow in calcareous regions are *Camptosorus rhizophyllus, Ruellia humilis, Arenaria patula, Frasera caroliniensis,* and *Carex plantaginea.*

Two coastal plain species found on the deposits are *Scleria ciliata* and *S. oligantha.*

Some of the rarer species collected were *Botrychium alabamense, Nemexia Hugeri, Epipactis repens* var. *ophioides, Liparis Loeselii, Hydrangea cinerea, Ilex Beadlei,* and *Evonymus obovatus.*

EXPLANATION OF CATALOG

In the catalog I have followed as closely as possible the Engler and Prantl System as revised by Robinson and Fernald in "Gray's New Manual of Botany," 1908. The most recent taxonomic publications have been used in determining the species and varieties. The deposits, and the communities on the deposits in which each species or variety was found, follow each species or variety listed in the catalog. Deposits are abbreviated by capital letters, and communities by small letters. For example:

Kalmia latifolia L.

DR: mbm, po

indicates that *Kalmia latifolia* L. was found on the Dark Ridge Deposit in maple-beech-birch-magnolia and pine-oak communities. The abbreviations of the deposits and the communities, and their meanings as employed in the catalog, have been explained on page 53.

A question mark following a plant name in the catalog indicates that the specimen lacks flowers or fruits for definite identification. An asterisk before the name indicates that the species is introduced.

CATALOG OF VASCULAR PLANTS

POLYPODIACEAE

Adiantum pedatum L.
CC: pas; DR: mbm, pd, po; HB: s; CH: og, pa; D9: mbm, og; LC: mbm; DB: mbm; F: mbm, pd; NG: pd.

Asplenium platyneuron (L.) Oakes
CC: pas, pd; D9: mbm, og; N: og; CH: os, pas; F: mbm, pd; NG: pas, pd; DB: mbm, pa, po; HB: pa, pd, po; DR: mbm, po; LC: po.

Asplenium Trichomanes L.
DR: pd, po; F: mbm; N: og; D9: mbm; LC: mbm, po.

Athyrium asplenioides (Michx.) Eaton
CC: pas; DR: mbm, pd; N: s; CH: og; D9: mbm; NG: pas, pd; DB: mbm; LC: mbm.

Athyrium thelypteroides (Michx.) Diels
CH: os; D9: mbm; N: s; DR: po; LC: po.

Camptosorus rhizophyllus (L.) Link
DR: mbm; F: mbm.

Cheilanthes lanosa (Michx.) Eaton
LC: po.

Cystopteris fragilis (L.) Bernh.
DR: mbm, po; F: mbm, pd; HB: s.

Dennstaedtia punctilobula (Michx.) Moore
DB: mbm, po; F: pd; N: og; DR: pd; LC: po.

Dryopteris hexagonoptera (Michx.) C. Chr.
CC: pas; D9: mbm; NG: pd; DR: mbm, pd, po; LC: mbm, po.

Dryopteris marginalis (L.) A. Gray
CH: pa; DR: mbm, pd, po; NG: pd; DB: mbm.

Dryopteris noveboracensis L.
DR: mbm, pd; LC: mbm, pa.

Dryopteris spinulosa (Retz.) Kuntze var. *intermedia* Underwood
CH: pa; F: mbm.

Onoclea sensibilis L.
DB: mbm; HB: s.

Polypodium polypodioides L.
CC: pas; CH: pa; LC: mbm, po.

Polypodium virginianum L.
DB: mbm; D9: og; F: mbm; DR: mbm, pd, po.

Polystichum acrostichoides (Michx.) Schott
CC: pas, pd; D9: mbm, og; N: og, s; CH: os, pa; F: mbm, pd; NG: pas, pd; DB: mbm, pa, po; HB: pd, po, s; DR: mbm, pd; LC: mbm, pa, po.
Polystichum acrostichoides (Michx.) Schott var. *incisum* Gray
DB: mbm.
Pteridium aquilinum L. var. *latiusculum* (Desv.) Underwood
CC: pas; DR: mbm; LC: mbm, po; CH: os, pa; F: mbm; NG: pas, pd; DB: mbm, po; HB: po.
Woodsia obtusa (Spreng.) Torr.
CC: pas, pd; DR: pd; D9: og.
Woodwardia areolata (L.) Moore
CH: mbm.

OSMUNDACEAE

Osmunda cinnamomea L.
CH: os; F: pd; NG: pd; DR: mbm, pd.
Osmunda Claytoniana L.
CH: mbm; DR: pd; F: mbm.
Osmunda regalis L. var. *spectabilis* Willd.
CH: os; DR: mbm, pd; LC: mbm, po; DB: mbm; D9: og.

SELAGINELLACEAE

Selaginella apoda L.
CC: pas.

OPHIOGLOSSACEAE

Botrychium alabamense Maxon
LC: pa, po.
Botrychium dissectum Sprengel var. *obliquum* (Muhl.) Clute
D9: mbm.
Botrychium dissectum Sprengel var. *tenuifolium* (Underwood) Farr.
CH: mbm.
Botrychium virginianum (L.) Swartze
CH: mbm, os; DR: mbm, pd; D9: mbm; DB: po.

EQUISETACEAE

Equisetum arvense L.
F: s.

PINACEAE

Juniperus virginiana L.
CC: pas; D9: mbm, og; NG: pas.
Pinus echinata Mill.
CC: pas, pd.
Pinus pungens Lamb.
HB: pd.

Pinus rigida Mill.
CC: pas, pd; DB: pa, po; HB: pa, po; CH: pa; DR: po.
Pinus Strobus L.
DB: mbm, pa, po; LC: mbm, po; N: og, os; HB: pa, pd, po.
Pinus virginiana Mill.
DB: po; HB: po; NG: pas, pd; D9: og; LC: pa, po.
**Thuja orientalis* L. var. *pyramidalis* Endl.
DR: pd.
Tsuga canadensis (L.) Carr.
DB: mbm; D9: og; LC: mbm, po; DR: mbm; F: s.

ALISMACEAE

Sagittaria latifolia Willd. var. *pubescens* (Muhl.) J. G. Sm.
DR: pd; F: s.

GRAMINEAE

**Agropyron repens* (L.) Beauv.
DB: mbm.
**Agrostis alba* L.
DB: mbm, pa; F: pd; NG: pas; HB: pd, s; N: s.
Agrostis hiemalis (Walt.) B.S.P.
CC: pd; CH: mbm; F: pd.
Agrostis perennans (Walt.) Tuckerm.
CC: pas, pd; HB: po, s; NG: pd; DB: po; LC: mbm; DR: mbm, pd; N: os.
Andropogon furcatus Muhl.
CH: pa; DB: po; NG: pd.
Andropogon scoparius Michx.
CH: os; F: pd; N: og; DB: mbm, po; HB: pa, pd.
**Anthoxanthum odoratum* L.
CH: mbm. pa; DR: pd; D9: og.
Aristida longespica Poir.
F: s.
**Arrhenatherum elatius* (L.) Mert. & Koch
N: og.
Arundinaria tecta (Walt.) Muhl.
CH: mbm, pa; LC: mbm.
Brachyelytrum erectum (Schreb.) Beauv.
DR: mbm; LC: mbm.
**Bromus commutatus* Schrad.
DB: mbm; HB: pd, s; NG: pd; DR: mbm.
**Bromus secalinus* L.
DR: mbm.
Cinna arundinacea L.
CH: mbm; DB: po.

**Dactylis glomerata* L.
CC: pas; HB: pd; NG: pd; F: s; N: og.
Danthonia sericea Nutt.
CH: pa; LC: po.
Danthonia spicata (L.) Beauv.
CH: pa, os; D9: og; N: s; DR: mbm, pd, po; F: mbm; NG: pas, pd.
**Digitaria ischaemum* (Schreb.) Muhl.
CC: pas; DB: po; F: mbm, s.
**Digitaria sanguinalis* (L.) Scop.
CC: pd; DR: pd; N: og, s.
Echinochloa colona (L.) Link
HB: s.
**Echinochloa crus-galli* (L.) Beauv.
DB: po; F: s; N: og, s; DR: pd; HB: s.
**Eleusine indica* (L.) Gaertn.
CC: pas; HB: pd; N: os; DR: pd.
Eragrostis capillaris (L.) Nees.
CC: pd; HB: s; N: og, os, pd.
Festuca elatior L.
DR: pd; NG: pas.
Festuca obtusa Spreng.
HB: s.
Festuca octoflora Walt.
D9: og.
Glyceria melicaria (Michx.) F. T. Hubb
DR: pd; NG: pd.
Glyceria striata (Lam.) Hitchc.
CH: mbm, pa; DR: mbm, pd; F: s; DB: mbm; D9: mbm; HB: s.
**Holcus lanatus* L.
DB: mbm, pa, po; F: s; NG: pas, pd; DR: pd; HB: po, s; D9: mbm; N: og, s.
Hystrix patula Moench.
DR: mbm.
Leersia oryzoides (L.) Swartz.
HB: s; F: s.
Leersia virginica Willd.
CC: pas; DR: pd; F: s; DB: po.
**Lolium multiflorum* Lam.
LC: po.
Melica mutica Walt.
LC: mbm, pa, po.
Muhlenbergia Schreberi Gmel.
F: pd, s; N: s; NG: pd.
Panicum auburne Ashe
CH: os; DB: mbm; NG: pas.

Panicum Boscii Poir.
CH: os; DR: mbm, pd, po; LC: mbm, po; DB: pa; D9: mbm.
Panicum Boscii Poir. var. *molle* (Vasey) Hitchc. & Chase
DB: po; D9: og; HB: po.
Panicum capillare L.
N: og, s.
Panicum clandestinum L.
DB: mbm; HB: pa, s; N: s; DR: mbm.
Panicum commutatum Schult.
CH: os; LC: mbm, pa, po; NG: pd.
Panicum commutatum Schult. var. *Ashei* (Pearson) Fernald
CH: pa; D9: mbm; N: os; DB: pa; HB: po; DR: mbm; LC: mbm, po.
Panicum depauperatum Muhl.
CH: os; LC: po.
Panicum dichotomum L.
CC: pas; DR: mbm; LC: mbm, po; CH: pa; D9: og; N: og; DB: pa; HB: pa, po; NG: pd.
Panicum lanuginosum Ell. var. *fasciculatum* Fernald
CC: pas, pd; DR: mbm, pd; HB: pd, s; CH: mbm, os; D9: mbm, og; LC: pa, po; DB: pa, po; F: mbm, pd; NG: pas, pd.
Panicum lanuginosum Ell. var. *septentrionale* Fernald
LC: mbm.
Panicum linearifolium Scribn.
CH: mbm, pa; LC: mbm, pa.
Panicum microcarpon Muhl.
CH: mbm; DB: mbm; N: s.
Panicum minus (Muhl.) Nash
DB: po.
Panicum sphaerocarpon Ell.
CH: mbm, pa; HB: pa; N: og; D9: og; LC: po.
Paspalum ciliatifolium Michx.
CC: pas.
Paspalum laeve Michx.
CC: pas.
Paspalum pubescens Muhl.
CC: pd; F: s; HB: s.
**Phleum pratense* L.
DB: mbm; F: pd; NG: pas, pd; DR: mbm, pd; HB: po.
**Poa annua* L.
NG: pd.
**Poa compressa* L.
CC: pas, pd; DR: pd; HB: pd; CH: mbm; D9: mbm; N: og, pd; DB: mbm; F: mbm; NG: pas, pd.
**Poa pratensis* L.
DR: pd.

Poa sylvestris Gray
CH: pa; NG: pas, pd.
**Setaria lutescens* (Weigel) F. T. Hubb
CC: pas; HB: pd; N: og, os.
Sorghastrum nutans (L.) Nash
CC: pd; F: pd.
Sphenopholis nitida (Spreng.) Scribn.
D9: mbm; N: os.
Sphenopholis obtusata (Michx.) Scribn.
DR: mbm; NG: pd.
**Sporobolus Berteroanus* (Trin.) H. & C.
N: s.
Stipa avenacea L.
CH: mbm; LC: mbm, pa, po.
Triodia flava (L.) Smyth
CC: pas; D9: mbm, og; HB: pd; CH: mbm.
Trisetum pennsylvanicum (L.) Beauv.
CH: mbm; LC: po.
Uniola latifolia Michx.
LC: po.

CYPERACEAE

Carex aestivalis M. A. Curtis
F: mbm.
Carex blanda Dewey
CC: pas; F: mbm.
Carex Bushii Mackenzie
D9: og.
Carex cephalophora Muhl.
CC: pas; DB: pa; D9: mbm, og; CH: mbm; DR: pd; N: s.
Carex digitalis Willd.
DB: mbm; F: mbm; LC: po.
Carex flexuosa Muhl.
N: s.
Carex Frankii Kunth.
HB: s.
Carex grisea Wahl.
HB: s.
Carex gynandra Schw.
D9: og.
Carex heterosperma Wald.
N: os.
Carex hirsutella Mackenzie
CH: mbm, os; D9: mbm, og.

Carex incomperta Bickn.
DB: mbm; DR: pd.
Carex laxiflora Lam.
D9: og; LC: mbm.
Carex laxiflora Lam. var. *gracillima* Boott
DR: pd; D9: mbm.
Carex leptalea Wahl.
DB: mbm.
Carex lucorum Willd.
F: s.
Carex lurida Wahl.
CC: pd; DR: pd; N: s; CH: mbm; F: s; DB: mbm; HB: s.
Carex Muhlenbergii Schk.
DB: mbm; N: s.
Carex pennsylvanica Lam.
DB: mbm; DR: pd; F: mbm.
Carex plantaginea Lam.
DR: mbm.
Carex rosea Schk.
CH: mbm; DR: mbm, pd; N: s; DB: mbm; D9: mbm; NG: pd.
Carex rosea Schk. var. *radiata* Dewey
NG: pd.
Carex scabrata Schw.
CH: mbm; DR: mbm; LC: po.
Carex scoparia Schk.
CH: os; N: s.
Carex stricta Lam.
F: s.
Carex varia Muhl.
DB: pa; D9: mbm; LC: po; DR: mbm; F: mbm; N: os.
Carex virescens Muhl.
CH: mbm; LC: mbm.
Carex vulpinoidea Michx.
CH: mbm; F: s; N: s; HB: s.
Cyperus cylindricus (Ell.) Britton
CC: pas.
Cyperus echinatus (Ell.) Wood
CC: pd.
Cyperus filiculmis Vahl var. *macilentus* Fernald
CC: pd.
Cyperus flavescens L.
CC: pas; HB: s; N: s.
Cyperus strigosus L.
CC: pas; DR: pd; N: s; CH: mbm, pa; F: s; DB: pa; HB: s.
Eleocharis acicularis (L.) R. & S.
F: s.

Eleocharis obtusa (Willd.) Schultes
CC: pas; F: s; HB: s; CH: mbm.
Fimbristylis autumnalis (L.) R. & S.
DR: pd; F: s.
Rhynchospora capitellata (Michx.) Vahl.
CH: mbm; F: s.
Scirpus atrovirens Muhl.
DB: pa; HB: s; N: s; F: s
Scirpus Cyperinus (L.) Kunth
DB: pa.
Scirpus lineatus Michx.
CH: mbm.
Scirpus polyphyllus Vahl.
HB: s.
Scirpus sylvaticus L.
F: s; N: s.
Scirpus validus Vahl.
N: s.
Scleria ciliata Michx.
D9: og; HB: pa; N: og.
Scleria oligantha Michx.
LC: mbm, po.

ARACEAE

Arisaema atrorubens (Ait.) Blume forma *viride* (Engler) Fernald
CC: pas; D9: mbm; NG: pas, pd; CH: mbm, os; F: mbm, pd; DR: mbm, pd, po; LC: po.
Arisaema atrorubens (Ait.) Blume forma *zebrinum* (Sims) Fernald
F: mbm.
Arisaema triphyllum (L.) Schott var. *montanum* Fernald
CC: pas.

COMMELINACEAE

Commelina communis L.
DB: mbm; N: s; NG: pd; D9: mbm.
Tradescantia subaspera Ker-Gawl var. *montana* (Shuttlew.) Anderson & Woodson
DB: po; DR: mbm, pd, po; F: pd.

JUNCACEAE

Juncus acuminatus Michx.
CC: pd; HB: s.
Juncus aristulatus Michx.
DB: mbm.
Juncus canadensis J. Gay
F: s; N: s.

Juncus canadensis J. Gay var. *subcaudatus* Engelm.
CH: mbm.
Juncus effusus L.
CH: mbm; F: s; N: s; DB: mbm; HB: s.
Juncus marginatus Rostk.
DB: mbm; DR: po; F: s.
Juncus secundus Beauv.
HB: pa, pd.
Juncus tenuis Willd.
CC: pas; DR: mbm, pd; N: os, s; CH: mbm; D9: og; NG: pas, pd; DB: pa, po; HB: s.
Luzula campestris (L.) DC. var. *bulbosa* A. Wood
CH: mbm, os; DR: pd; NG: pas, pd; DB: po.
Luzula saltuensis Fernald
LC: mbm, po.

LILIACEAE

Aletris farinosa L.
CH: pa; DR: mbm.
Chamaelirium luteum (L.) A. Gray
CH: mbm, pa; F: pd; LC: mbm, po; DR: mbm.
Clintonia umbellulata Michx.
DR: mbm; F: mbm.
Disporum lanuginosum (Michx.) Nichols
DR: mbm.
Erythronium americanum Ker. ?
F: mbm.
**Hemerocallis fulva* L.
HB: s.
Lilium carolinianum Michx.
CH: pa; DR: mbm; HB: pa, po; DB: pa.
Medeola virginiana L.
DB: mbm; LC: mbm.
Nemexia herbacea (L.) Small
DB: mbm; DR: mbm, pd.
Nemexia Hugeri Small
CH: os; D9: mbm, og.
Oakesia puberula (Michx.) Wats.
DR: mbm; LC: mbm; N: os; F: mbm.
Polygonatum biflorum (Walt.) Ell.
DB: mbm; D9: mbm; LC: po; DR: mbm.
Polygonatum commutatum (Schultes) A. Dietrich
DB: mbm, po; DR: mbm.
Smilacina racemosa Desf.
DB: mbm, pa, po; D9: og; F: mbm; DR: mb

Smilax glauca Walt.
CC: pas; DR: mbm, pd; HB: pd; CH: mbm, os, pa; D9: mbm, og; LC: mbm, po; DB: pa, po; F: pd; NG: pd.
Smilax rotundifolia L. var. *quadrangularis* (Muhl.) Wood
CC: pd; D9: og; N: og; CH: mbm, os; F: mbm, pd; NG: pas; DB: mbm, pa; HB: pa, pd; DR: pd, po; LC: mbm.
Stenanthium gramineum (Ker.) Morong
CH: pa; DB: mbm, pa, po.
Trillium Catesbaei Ell.
CH: mbm.
Trillium erectum L.
DR: mbm.
Trillium erectum L. var. *album* (Michx.) Pursh
DB: mbm.
Trillium Gleasoni Fernald
CH: mbm; DR: mbm.
Trillium Gleasoni Fernald x *T. Vaseyi* Harbison var. *simile* Gleason
D9: mbm.
Uvularia grandiflora J. E. Smith
DR: mbm.
Yucca filamentosa L. var. *concava* Baker ?
LC: po.

DIOSCOREACEAE

Dioscorea glauca Muhl.
NG: pd.
Dioscorea villosa L.
DR: mbm, pd, po.

AMARYLLIDACEAE

Hypoxis hirsuta (L.) Coville
CH: pa; LC: mbm; NG: pas; DR: mbm; N: os.

IRIDACEAE

Iris cristata Ait.
CH: mbm; DB: po; LC: po; DB: po; F: mbm.
Sisyrinchium angustifolium Mill.
CH: pa; DR: pd.
Sisyrinchium gramineum Curtis
DB: mbm; N: s; NG: pas, pd; LC: po.
Sisyrinchium mucronatum Michx.
CH: mbm, pa; D9: og; LC: pa, po.

ORCHIDACEAE

Aplectrum hyemale (Muhl.) Torr.
CH: mbm; DR: mbm.

Corallorhiza odontorhiza Nutt.
LC: mbm.
Cypripedium acaule Ait.
HB: po.
Cypripedium parviflorum Salisb.
F: mbm.
Epipactis pubescens (Willd.) A. A. Eaton
F: mbm; LC: mbm; N: os.
Epipactis repens (L.) Crantz var. *ophioides* (Fernald) A. A. Eaton
DB: mbm.
Habenaria ciliaris (L.) R. Br.
CH: mbm; DR: po.
Habenaria clavellata (Michx.) Spreng.
CH: mbm.
Habenaria lacera (Michx.) R. Br.
NG: pd.
Liparis liliifolia (L.) L. C. Rich
CH: os; D9: mbm; LC: mbm; DR: mbm.
Liparis Loeselii (L.) L. C. Rich
DR: mbm.
Orchis spectabilis L.
F: mbm.
Spiranthes gracilis (Bigel.) Beck
CC: pas; D9: mbm; LC: mbm, pa, po; CH: pa; F: pd; N: og.
Spiranthes tuberosa Raf.
HB: pd.
Tipularia discolor (Pursh) Nutt.
LC: mbm.

SALICACEAE

**Populus candicans* Ait.
DB: mbm; F: s.
Salix humilis Marsh
CH: mbm.
Salix nigra Marsh
CC: pas; F: s; N: s; CH: mbm; HB: s.
Salix sericea Marsh
CC: pd; F: s; HB: pd, s; DB: mbm.

JUGLANDACEAE

Carya alba (L.) K. Koch
CC: pas; DR: mbm, po; LC: mbm; DB: mbm.
Carya glabra (Mill) Spach
CC: pd; NG: pas, pd.

Carya glabra (Mill) Spach var. *villosa* (Sarg.) Robinson
CC: pas; D9: mbm; NG: pas; CH: pa.
Juglans cinerea L.
DR: mbm, pd.
Juglans nigra L.
CC: pas, pd; HB: pd, s; LC: mbm.

BETULACEAE

Alnus rugosa (Du Roi) Spreng.
CH: os, pa; F: pd, s; N: s; DR: pd; HB: s.
Betula lenta L.
CH: os; F: mbm, pd; NG: pas; DB: mbm, po; HB: pa; D9: mbm; N: og, os, s.
Betula lutea Michx.
DB: mbm; DR: mbm.
Carpinus caroliniana Walt.
DR: mbm, pd; F: mbm; N: s; D9: mbm, og.
Corylus americana Walt.
CH: os; D9: mbm, og; N: og; DR: mbm.
Corylus rostrata Ait.
HB: po; N: og.
Ostrya virginiana (Mill) Willd.
HB: po.

FAGACEAE

Castanea dentata (Marsh) Borkh.
DB: pa; D9: mbm; NG: pd; DR: mbm, po; HB: po.
Castanea pumila (L.) Mill
DB: pa; HB: pa, po, s; N: os; D9: og; LC: po; NG: pas, pd.
Fagus grandifolia Ehrh.
CH: os; F: mbm; LC: po; DB: mbm; HB: po; N: os.
Quercus alba L.
CC: pas, pd; DR: mbm; N: og; CH: os; D9: mbm, og; NG: pas, pd; DB: mbm, pa, po; LC: mbm.
Quercus borealis Michx. f. var. *maxima* (Marsh) Ashe
CC: pd; F: mbm; N: og, s; DB: pa, po; HB: po; NG: pas, pd; DR: mbm, po; LC: po.
Quercus coccinea Muench.
CH: pa, os; D9: mbm, os; NG: pd; DB: mbm, pa; F: pd; DR: mbm; N: po.
Quercus falcata Michx.
CC: pas; D9: mbm, og; LC: pa, po; CH: pa; HB: pa, pd, po.
Quercus imbricaria Michx.
D9: mbm, og.
Quercus montana Willd.
CC: pas; DB: mbm; D9: mbm; CH: os; DR: mbm; NG: pas, pd.

Quercus stellata Wang.
CC: pd; DR: mbm; LC: pa, po; CH: os, pa; D9: og; N: og, os; DB: mbm, pa, po; HB: pa, pd, po, s.
Quercus velutina Lam.
CC: pas; DB: po; NG: pas, pd; CH: os; N: og, os.

URTICACEAE

Boehmeria cylindrica (L.) Sw.
DB: po.
Laportea canadensis (L.) Gaud.
CC: pas; DB: mbm; DR: mbm.
Maclura pomifera (Raf.) Schneider
HB: s.
Morus rubra L.
HB: pd, po; DR: mbm; D9: mbm.
Pilea pumila (L.) Gray
HB: s; F: s.
Ulmus fulva Muhl.
DR: mbm.

SANTALACEAE

Pyrularia pubera Michx.
CH: mbm; D9: og; N: os; DB: mbm; HB: po; DR: mbm; LC: po.

ARISTOLOCHIACEAE

Aristolochia macrophylla Lam.
DR: mbm, pd; F: mbm.
Asarum canadense L.
DR: mbm.
Asarum grandiflorum (Michx.) Small
LC: mbm, po.

POLYGONACEAE

Polygonum buxiforme Small
DR: pd.
Polygonum dumetorum L.
CC: pas; F: s; NG: pd; DR: pd; HB: s.
Polygonum erectum L.
HB: pd.
Polygonum Hydropiper L.
CC: pas; F: s; NG: pd; HB: pd; N: og.
Polygonum hydropiperoides Michx.
DR: pd; HB: s.
Polygonum neglectum Besser
N: s.

Polygonum pennsylvanicum L.
DR: pd; HB: s; N: s; F: s.
**Polygonum Persicaria* L.
CC: pas; F: mbm; N: og, s; DB: po; HB: pd, s; NG: pas.
Polygonum punctatum (Ell.) Small
LC: mbm; N: s.
Polygonum sagittatum L.
DB: po; F: s; N: s; DR: pd; HB: s.
Polygonum tenue Michx.
DR: pd.
Polygonum virginianum L.
CC: pas; DR: pd; NG: pd; CH: mbm; HB: s.
**Rumex Acetosella* L.
CC: pas, pd; DR: pd; N: og, os; CH: mbm; F: pd, s; NG: pas, pd; DB: mbm, po; HB: pd, po, s.
**Rumex crispus* L.
CH: mbm; D9: mbm; N: s.
**Rumex obtusifolius* L.
CC: pas; DR: mbm, pd; NG: pas, pd; DB: mbm; HB: pd, s.

CHENOPODIACEAE

**Chenopodium ambrosioides* L.
CC: pas; F: pd; N: og; DR: pd; HB: po.
**Chenopodium album* L.
DR: po; N: og, s; NG: po; HB: pa, pd.

AMARANTHACEAE

**Amaranthus hybridus* L.
DR: pd; N: og, os, s.

PHYTOLACCACEAE

Phytolacca americana L.
CC: pas; DR: pd; HB: pa, pd, po; CH: os; D9: og; N: og, s; DB: mbm, pa, po; F: pd, s; NG: pas, pd.

ILLECEBRACEAE

Anychia canadensis (L.) B. S. P.
DB: mbm; NG: pd.
Anychia polygonoides Raf.
DB: pa, po; F: pd, s; N: og; D9: og.

CARYOPHYLLACEAE

Arenaria patula Michx.
DR: pd.

Arenaria serpyllifolia L.
F: mbm, pd, s; N: og; NG: pd.
**Cerastium viscosum* L.
CC: pd; D9: og; N: os; CH: mbm; F: mbm, s; NG: pd; DR: mbm, pd; HB: po.
**Cerastium vulgatum* L.
CC: pas, pd; N: og, os; NG: pas, pd; F: s.
**Dianthus Armeria* L.
CH: mbm; F: pd, s; NG: pas, pd; DB: mbm, pa, po; HB: pd.
**Lychnis alba* Mill
F: s.
Sagina decumbens (Ell.) T. & G. var. *Smithii* (Gray) Wats.
LC: po.
**Saponaria officinalis* L.
HB: s.
Silene antirrhina L.
DR: pd; D9: og.
Silene noctiflora L.
NG: pd.
Silene stellata (L.) Ait. f.
F: mbm.
Silene virginica L.
CC: pas, pd; D9: mbm, og; LC: po; DB: po; F: pd, s; NG: pd; DR: mbm, pd; HB: pa.
Stellaria graminea L.
DB: mbm.
Stellaria media (L.) Cyrill.
DR: pd; NG: pd.
Stellaria pubera Michx.
DR: mbm, pd.

PORTULACACEAE

Portulaca oleracea L.
DB: mbm.

RANUNCULACEAE

Aconitum uncinatum L.
D9: mbm.
Actaea alba (L.) Mill
DR: mbm; LC: mbm, po.
Anemone virginiana L.
DB: mbm; HB: po; NG: pd; DR: mbm, pd; LC: mbm; D9: mbm, og; N: og.
Aquilegia canadensis L.
F: mbm.

Cimicifuga racemosa (L.) Nutt.
CH: mbm; D9: mbm; HB: po; DR: mbm, pd.
Clematis Beadlei (Small) Erickson
LC: mbm.
Clematis Viorna L.
DR: pd; F: pd.
Clematis virginiana L.
DB: mbm, po; F: s; NG: pd.
**Delphinium Ajacis* L.
F: s.
Hepatica acutiloba DC.
DR: mbm; F: mbm.
Ranunculus abortivus L.
NG: pd.
**Ranunculus acris* L.
F: s; N: po, s.
Ranunculus hispidus Michx.
NG: pd.
Ranunculus recurvatus Poir.
CC: pas, pd; DR: mbm, pd; HB: s; CH: mbm; D9: mbm; NG: pas, pd; DB: mbm; F: s.
Ranunculus repens L.
DR: pd.
Ranunculus sceleratus L.
N: os.
Thalictrum clavatum DC.
DB: mbm; DR: mbm; F: s.
Thalictrum dioicum L.
CH: mbm.
Thalictrum polygamum Muhl.
DB: po.
Thalictrum revolutum DC.
CH: mbm, pa, os; DR: mbm, po; HB: pa, po; DB: mbm, pa, po; D9: mbm, og; N: og.
Zanthorhiza apiifolia L'Her.
CH: mbm, pa; LC: mbm, po; N: s.

MAGNOLIACEAE

Liriodendron tulipifera L.
CC: pas; DR: mbm, pd, po; LC: po; CH: os; D9: mbm, og; N: s; DB: pa; HB: pd; NG: pd.
Magnolia acuminata L.
DB: mbm, pa, po; DR: mbm, pd, po; D9: mbm, og.
Magnolia Fraseri Walt.
DR: mbm; F: mbm; LC: mbm, po.

CALYCANTHACEAE

Calycanthus fertilis Walt.
CH: pa; DR: mbm.
Calycanthus nanus (Loisel) Small
CC: pas; DR: mbm.

ANONACEAE

Asimina triloba (L.) Dunal
LC: mbm.

BERBERIDACEAE

Caulophyllum thalictroides L.
CC: pas; DR: mbm, pd.
Podophyllum peltatum L.
CC: pd; D9: mbm; NG: pd; CH: os; LC: mbm; DR: mbm; N: os.

LAURACEAE

Benzoin aestivale (L.) Nees.
CC: pas; DR: po; N: pas CH: os; D9: og; NG: pd; DB: mbm; HB: pd, s.
Sassafras albidum (Nutt.) Nees.
CC: pas; DR: mbm, pd; LC: mbm, po; CH: pa, os; D9: mbm, og; N: og, s; DB: mbm, pa, po; HB: pa, po, s; NG: pd.

PAPAVERACEAE

Sanguinaria canadensis L.
CC: pas; D9: mbm; NG: pd; CH: mbm, pa; F: mbm, pd; DR: mbm, pd; LC: po.

CRUCIFERAE

**Arabidopsis thaliana* (L.) Britton
HB: s.
Arabis canadensis L.
CH: os; DR: mbm; NG: pas, pd.
Arabis laevigata (Muhl.) Poir.
DR: pd.
**Barbarea verna* (Mill) Aschers
HB: s.
**Barbarea vulgaris* R. Br.
DR: pd.
**Brassica japonica* Siebold
DR: pd.
**Brassica nigra* (L.) Koch.
DR: pd.
**Brassica rapa* L.
N: s.

**Capsella Bursa-pastoris* (L.) Medic
CC: pas; DR: pd; N: os.
Cardamine pennsylvanica Muhl.
N: s.
Dentaria heterophylla Nutt.
DR: mbm.
**Lepidium campestre* (L.) R. Br.
HB: pa; N: og, s.
Lepidium virginicum L.
CC: pas, pd; DR: mbm, pd; N: og, os, s; CH: mbm; F: pd, s; NG: pas; DB: pa; HB: pd, po.
**Sisymbrium altissimum* L.
DR: pd.
**Sisymbrium officinale* (L.) Scop.
CC: pas; HB: pd; NG: pas; DR: pd; N: og, s.
**Thlaspi arvense* L.
DR: pd.

CRASSULACEAE

Sedum ternatum Michx.
DB: mbm; HB: s; NG: pas, pd; F: mbm.

SAXIFRAGACEAE

Astilbe biternata (Vent.) Britton
CH: mbm; DR: mbm; D9: mbm; DB: mbm.
Heuchera americana L.
CH: mbm; HB: a; N: og.
Heuchera villosa Michx.
DR: mbm; F: pd; LC: mbm.
Hydrangea arborescens L.
CC: pas; D9: mbm; NG: pas, pd; CH: mbm, pa; F: mbm: DR: mbm, pd· LC: mbm.
Hydrangea cinerea Small
LC: mbm.
Mitella diphylla L.
CC: pas; DR: mbm.
Tiarella cordifolia L.
DR: mbm; LC: mbm, po.

HAMAMELIDACEAE

Hamamelis virginiana L.
DB: mbm; F: mbm, pd; LC: mbm; DR: mbm, po.
Liquidambar Styraciflua L.
LC: mbm, po.

PLATANACEAE

Platanus occidentalis L.
CC: pd; D9: og; HB: pd, s; CH: og; F: s.

ROSACEAE

Agrimonia parviflora Soland.
CC: pas; DB: po; HB: pd, po, s; CH: pa.
Agrimonia rostellata Wallr.
NG: pd.
Agrimonia striata Michx.
DR: pd; D9: og.
Amelanchier canadensis (L.) Medic.
HB: pa, po; LC: po.
Amelanchier laevis Wiegand
CH: mbm; DR: pd.
Aruncus allegheniensis Rydb.
DB: mbm; F: s.
Aruncus Aruncus (L.) Karst.
CH: mbm.
**Chaenomeles lagenaria* (Loisel) Koidz.
F: s.
Crataegus collina Chapm.
HB: s; F: pd.
Crataegus Crus-galli Chapm.
CC: pd; F: s; HB: pd, s; DR: pd.
Crataegus macrosperma Ashe
F: pd; LC: po; NG: pas; HB: pd, s; N: og, s.
Fragaria virginiana Duchesne
CH: mbm; DR: pd; NG: pas, pd.
Geum canadense Jacq.
CC: pas; DR: mbm; NG: pd, s; DB: mbm; HB: pd, s.
Geum hirsutum Muhl.
DR: pd.
Gillenia trifoliata Moench.
CH: pa; DR: mbm, pd; LC: mbm; DB: po.
Malus angustifolia (Ait.) Michx.
CH: os; LC: po; N: og.
Malus coronaria (L.) Mill.
CC: pd; F: pd.
Malus glabrata Rehder
HB: po; NG: pd.
**Malus Malus* (L.) Britton
DB: mbm, pa; HB: pa; NG: pas, pd; D9: og.
Malus platycarpa Rehder
DB: pa; HB: pd.

Physocarpus opulifolius (L.) Maxim.
CH: pa, os.
Potentilla canadensis L.
CH: pas, pd; NG: pas, pd.
Potentilla monspeliensis L.
DR: mbm, pd; HB: s; NG: pd.
Potentilla pumila Poir.
CC: pd; DR: pd.
Potentilla recta L.
DR: pd.
Prunus americana Marsh
D9: og; HB: s.
**Prunus Avium* L.
HB: s.
**Prunus Cerasus* L.
DR: pd.
**Prunus Persica* (L.) Stokes
CH: os.
Prunus virginiana L.
CH: mbm; F: mbm; NG: pd; DB: mbm; HB: pa, pd, s; D9: og; N: s.
Rosa carolina L.
CH: pa; HB: s.
**Rosa damascena* Mill
DR: pd.
Rosa palustris Marsh
D9: mbm; F: s.
Rosa setigera Michx. var. *tomentosa* T. & G.
HB: po.
Rubus allegheniensis Porter
CH: pa; DR: mbm; NG: pas, pd; DB: pa; F: pd, s.
Rubus argutus Link
CC: pas, pd; D9: mbm, og; N: og, os, s; CH: mbm, pa, os; F: s; NG: pas, pd; DB: mbm, pa; HB: pd, s; DR: pd; LC: po.
Rubus canadensis L.
DB: pa.
Rubus flagellaris Willd.
CH: pa, os; N: og; NG: pas; LC: po.
Rubus occidentalis L.
CH: os; D9: mbm, og; N: os; DB: mbm, pa, po; HB: po, s; NG: pd; DR: mbm, pd; LC: mbm.
Rubus odoratus L.
DR: mbm; F: pd.
Spiraea alba Du Roi
F: pd.
Waldsteinia fragarioides (Michx.) Tratt.
LC: mbm, po.

LEGUMINOSAE

Amorpha fruticosa L.
NG: pas, pd.
Amphicarpa monoica (L.) Ell.
CC: pas; DR: mbm; HB: s; CH: mbm; D9: mbm; LC: mbm; DB: po; F: s; N: s.
Apios tuberosa Moench.
DB: po; F: mbm; HB: s.
Baptisia tinctoria (L.) R. Br.
CH: mbm, pa.
Cassia chamaecrista Chapm.
CH: mbm.
Cassia nictitans L.
CC: pas; LC: mbm; N: og; DB: po.
Centrosema virginianum (L.) Benth.
LC: po.
Desmodium canadense (L.) DC.
DB: po.
Desmodium ciliare DC.
CH: mbm; HB: pa; LC: po; D9: mbm.
Desmodium laevigatum (Nutt.) DC.
DB: po; HB: po.
Desmodium marilandicum (L.) DC.
DB: po.
Desmodium nudiflorum (L.) DC.
DR: mbm; D9: mbm; LC: mbm, pa.
Desmodium paniculatum (L.) DC.
CC: pd; DR: pd; NG: pd.
Desmodium paniculatum (L.) DC. var *pubens* T. & G
CH: mbm; HB: pd; NG: pd; DB: po.
Desmodium rhombifolium (Ell.) DC.
DB: po; N: og.
Desmodium rigidum (Ell.) DC.
CH: pa; DR: po; LC: mbm; DB: pa.
Desmodium rotundifolium (Michx.) DC.
LC: pa.
Desmodium viridiflorum (L.) Beck.
CH: mbm; LC: mbm.
Gleditsia triacanthos L.
HB: po.
Lespedeza hirta (L.) Ell.
CH: pa; DR: mbm; HB: pa; DB: pa, po; D9: og; LC: pa.
Lespedeza Nuttallii Darl.
DR: mbm; LC: mbm.

Lespedeza procumbens Michx.
CC: pd; D9: mbm, og.
Lespedeza repens (L.) Bart.
LC: pa, pd; D9: og.
Lespedeza virginica (L.) Britton
CH: mbm; HB: s.
**Medicago sativa* L.
HB: pd.
**Melilotus alba* Desv.
HB: pd.
Robinia Pseudo-Acacia L.
CC: pd; DR: mbm; HB: pa, pd, po, s; CH: pa; D9: mbm, og; N: og; DB: mbm, pa, po; F: pd; NG: pas, pd.
Schrankia angustata T. & G.
LC: po.
Stylosanthes biflora (L.) B. S. P.
CH: pa.
Stylosanthes riparia Kearney
CC: pas; D9: mbm, og; N: og; CH: os; HB: po.
**Trifolium agrarium* L.
N: og.
**Trifolium arvense* L.
HB: s.
**Trifolium hybridum* L.
N: s.
**Trifolium pratense* L.
CC: pas; DR: pd; HB: pd, s; DB: mbm, pa; F: s; N: og.
**Trifolium procumbens* L.
CC: pas, pd; D9: og; F: s; CH: mbm.
Trifolium repens L.
CC: pas, pd; D9: mbm; N: s; CH: mbm; F: mbm; NG: pas, pd; DR: pd; HB: pd.
Vicia caroliniana Walt.
CH: pa; DR: pd; F: mbm; DB: po; D9: og; LC: po.
**Vicia sativa* L.
HB: s

LINACEAE

Linum virginianum L.
CH: pa; D9: og; LC: po; DR: mbm; HB: po.

OXALIDACEAE

Oxalis corniculata L.
CH: mbm, pa; DB: mbm.

Oxalis cymosa Small
CH: pa; F: pd, s; NG: pd; DR: po; N: og.
Oxalis filipes Small
CH: os; N: os.
Oxalis stricta L.
CC: pas, pd; DR: pd; HB: pa; CH: mbm.
Oxalis violacea L.
CC: pas, pd.

GERANIACEAE

Geranium carolinianum L.
CC: pas; CH: mbm; HB: pd, s.
Geranium maculatum L.
D: mbm, pd; F: mbm; NG: pd; D9: mbm.

POLYGALACEAE

Polygala polygama Walt.
LC: mbm, pa, po.
Polygala Senega L.
DR: mbm, pd.
Polygala verticillata L.
CC: pd; D9: og; N: og; DB: pa.

EUPHORBIACEAE

Acalypha rhomboidea Raf.
DR: pd.
Acalypha virginica L.
CC: pd.
Euphorbia corollata L.
CH: pa, os; DR: mbm; HB: pd, po; DB: pa, po; D9: mbm, og; LC: po.
Euphorbia hyssopifolia L.
HB: s; NG: pd.

ANACARDIACEAE

Rhus copallina L.
CC: pas; DR: mbm; LC: po.
Rhus glabra L.
CH: pa; DR: mbm; HB: pd; DB: mbm, po; D9: og; N: s.
Rhus hirta (L.) Sudw.
DB: po.
Rhus Toxicodendron L. var. *radicans* (L.) Torr.
CH: mbm.

AQUIFOLIACEAE

Ilex Beadlei Ashe
CC: pd.

Ilex monticola A. Gray
CH: mbm.
Ilex opaca Ait.
LC: mbm, po.

CELASTRACEAE

Evonymus americanus L.
CH: mbm; D9: mbm; LC: mbm, po; DR: mbm.
Evonymus obovatus Nutt.
DR: mbm.

ACERACEAE

Acer pennsylvanicum L.
DR: mbm; F: mbm.
Acer rubrum L.
CH: pa; D9: mbm, og; LC: mbm, pa, po; DB: mbm, po; F: mbm, pd; N: og, os; DR: mbm, pd; HB: pa, pd, po; NG: pas, pd.
Acer saccharum Marsh
DR: mbm.

SAPINDACEAE

Aesculus octandra L.
CC: pas, pd; F: mbm, pd, s; N: s; DR: pd, po; LC: mbm.

BALSAMINACEAE

Impatiens biflora Walt.
CH: mbm; DB: mbm; HB: s.
Impatiens pallida Walt.
DB: mbm; DR: mbm.

RHAMNACEAE

Ceanothus americanus L.
CH: pa, os; D9: mbm, og; N: os; DB: mbm, pa, po; HB: pa, po; NG: pd; DR: mbm; LC: mbm, pa, po.

MALVACEAE

**Abutilon Abutilon* (L.) Rusby
DR: pd.
**Malva rotundifolia* L.
HB: pd.

HYPERICACEAE

Ascyrum hypericoides L.
CC: pas; DR: pd; LC: pa.
Hypericum canadense L.
DR: pd.

Hypericum mutilum L.
CC: pas; HB: s.
Hypericum perforatum L.
DB: mbm; DR: mbm; HB: s.
Hypericum punctatum Lam.
CC: pas; D9: og; N: og, os, s; CH: pas, os; F: mbm, pd; NG: pas, pd; DB: pa, po; HB: pa, pd, po; DR: mbm, pd; LC: pa.

VIOLACEAE

Viola affinis LeConte
DB: mbm, po; F: mbm; N: og.
Viola blanda Willd.
DR: mbm, pd; LC: po; N: os; F: mbm, s.
Viola canadensis L.
DR: mbm.
Viola cucullata Ait.
CH: mbm; DR: mbm; N: s; DB: po; F: mbm.
Viola eriocarpa Schwein.
DR: mbm.
Viola fimbriatula J. E. Smith
N: og.
Viola hastata Michx.
F: mbm; LC: mbm.
Viola pallens (Banks) Brainerd
DB: mbm.
Viola palmata L.
CH: mbm; Lc: po; NG: pd; DR: pd.
Viola papilionacea Pursh
CH: mbm; D9: mbm, og; HB: s.
Viola pedata L.
CH: pa; DR: mbm; HB: po; DB: pa; D9: og; N: og
Viola primulifolia L.
LC: pa, po.
Viola pubescens Ait.
F: mbm.
Viola rotundifolia Michx.
F: mbm; LC: po.
Viola sagittata Ait.
LC: mbm, po.
Viola sororia Willd.
DB: mbm; F: pd.
Viola Walteri House
LC: mbm, po.

PASSIFLORACEAE

Passiflora lutea L.
CC: pas; DR: mbm, pd.

LYTHRACEAE

Cuphea petiolata (L.) Koehne
CH: os; DR: pd; NG: pd.

VITACEAE

Psedera quinquefolia (L.) Greene
CH: mbm; DB: po.
Psedera quinquefolia (L.) Greene var. *hirsuta* (Donn) Rehder
DB: mbm; HB: s; NG: pas; DR: pd; LC: mbm, po; D9: mbm, og; N: og, pd.
Vitis aestivalis Michx.
DB: po; HB: pd.
Vitis bicolor LeConte
DB: mbm; N: os; NG: pas, pd; HB: s.
Vitis cinerea Engelm.
DB: mbm; D9: mbm.
Vitis cordifolia Michx.
CC: pas; DR: pd; HB: pd, po, s; CH: mbm.
Vitis labrusca L.
DB: pa; DR: pd; HB: s.
Vitis rotundifolia Michx.
LC: mbm, po.

TILIACEAE

Tilia neglecta Spach
DR: mbm; F: mbm.

MELASTOMACEAE

Rhexia virginica L.
DR: pd.

ONAGRACEAE

Circaea latifolia Hill
DR: mbm, pd; D9: mbm; NG: pd.
Epilobium coloratum Muhl.
DR: pd; HB: s; NG: pd; F: s
Gaura biennis (L.) Ell.
DB: po; DR: pd; HB: s.
Ludvigia palustris (L.) Ell.
HB: s.

Oenothera biennis L.
CH: mbm; DR: pd; HB: pd, s; DB: mbm; F: s.
Oenothera fruticosa L.
CH: pa.
Oenothera fruticosa L. var. *hirsuta* Nutt.
NG: pas, pd.
Oenothera pumila L.
F: s.

ARALIACEAE

Aralia nudicaulis L.
DR: mbm.
Aralia racemosa L.
DR: mbm.

UMBELLIFERAE

Angelica villosa (Walt.) B. S. P.
DR: mbm; HB: pd; LC: mbm; D9: og.
Cicuta maculata L.
DB: mbm; HB: pd, s.
Cryptotaenia canadensis (L.) DC.
CC: pas; DR: mbm; HB: s; DB: mbm; D9: mbm.
**Daucus Carota* L.
DR: pd; N: og; NG: pas; HB: pd, s.
Eryngium aquaticum L.
CH: pa.
Ligusticum canadense (L.) Britton
LC: mbm.
Osmorhiza Claytoni (Michx.) Clarke
DR: mbm.
Oxypolis rigidior (L.) Coult. & Rose
CH: mbm; DR: mbm, pd; N: s; DB: po.
Sanicula canadensis L.
CC: pas; DR: mbm, pd; LC: mbm; CH: os; D9: mbm, og; N: og, os; DB: mbm; HB: pd, po, s; NG: pas, pd.
Sanicula marilandica L.
DR: mbm.
Sium cicutaefolium Schrank.
DR: mbm.
Thaspium aureum Nutt.
CH: mbm, os, pa; LC: mbm, po; NG: pas; D9: og.
Thaspium aureum Nutt. var. *atropurpureum* (Desr.) Coult. & Rose
CH: pa; DR: mbm, pd.
Thaspium barbinode (Michx.) Nutt.
DR: mbm.

Zizia Bebbii (Coult. & Rose) Britton
DR: mbm; LC: mbm; NG: pd; F: mbm.
Zizia cordata (Walt.) DC.
DR: mbm; D9: mbm.

CORNACEAE

Cornus alternifolia L.f.
CC: pas; DR: mbm, pd; N: os; DB: mbm, po; LC: po.
Cornus florida L.
CC: pd; D9: mbm, og; N: og; DB: mbm; HB: pd, po, s; NG: pas, pd; DR: mbm, pd; LC: mbm, po.
Nyssa sylvatica Marsh
CC: pas, pd; DR: mbm; N: os; CH: pa, os; D9: og; DB: pa, po; LC: mbm, po.

ERICACEAE

Chimaphila maculata (L.) Pursh
CH: pa, os; HB: pa, po; NG: pas, pd; DB: pa; LC: mbm, pa, po; D9: mbm; N: os.
Clethra acuminata Michx.
CH: pa; DR: mbm; F: mbm.
Epigaea repens L.
DB: pa, po; LC: pa, po; NG: pd; DR: po; N: og, os.
Gaultheria procumbens L.
CH: pa; F: mbm; N: og, os; DR: po.
Gaylussacia baccata Wang.
CH: pa; F: mbm; N: og, os; DR: po; HB: po.
Gaylussacia ursina M. A. Curtis
LC: mbm, po.
Hypopitys americana (DC.) Small
F: mbm; LC: pa.
Hypopitys lanuginosa (Michx.) Nutt.
D9: mbm; LC: po.
Kalmia latifolia L.
CC: pd; D9: mbm, og; N: og, os, s; CH: mbm, pa, os; F: mbm, pd; NG: pas, pd; DB: mbm, pa, po; HB: pa, po; DR: mbm, pd, po; LC: mbm, pa, po.
Leucothoe Catesbaei (Walt.) A. Gray
CH: os; DR: mbm, pd; LC: mbm.
Leucothoe recurva (Buckley) A. Gray
DR: mbm; F: mbm.
Lyonia ligustrina (L.) DC.
CH: pa, os; DR: mbm; LC: pa, po; DB: po; HB: po.
Lyonia ligustrina (L.) DC. var. *foliosiflora* (Michx.) Fernald
DB: mbm; HB: pa; NG: pd.
Monotropa uniflora L.
DB: mbm; DR: mbm.

Oxydendrum arboreum (L.) DC.
CC: pas; DR: mbm; LC: pa, po; CH: pa; D9: mbm, og; N: os; DB: mbm, pa, po; HB: pa, pd, po.
Rhododendron calendulaceum (Michx.) Torr.
CC: pas; D9: og; N: os, s; CH: mbm, os, pa; F: mbm, s; NG: pas, pd; DB: pa, po; HB: po; DR: mbm, pd, po; LC: pa, po.
Rhododendron maximum L.
CH: pa; F: mbm, pd; NG: pd; DB: mbm, pa, po; LC: mbm, po; DR: pd, po; N: og, os.
Vaccinium corymbosum L.
CH: pa.
Vaccinium melanocarpum Mohr.
CH: mbm, pa.
Vaccinium neglectum (Small) Fernald
DB: pa, po; HB: pa; LC: mbm.
Vaccinium pallidum Ait.
CH: mbm; HB: po; LC: mbm, pa, po; DR: po.
Vaccinium stamineum L.
CH: mbm, pa; D9: mbm, og; HB: pa, pd, po; DR: po.

DIAPENSIACEAE

Galax aphylla L.
CH: pa; DR: mbm; LC: mbm, po; DB: mbm, po; F: mbm.

PRIMULACEAE

* *Lysimachia Nummularia* L.
DB: mbm; F: s; HB: s.
Lysimachia quadrifolia L.
CH: mbm, os, pa; DR: mbm, pd; LC: mbm; DB: mbm; D9: mbm, og.
Steironema ciliatum (L.) Raf.
HB: s.
Steironema hybridum (Michx.) Raf.
D9: mbm, og.

EBENACEAE

Diospyros virginiana L.
CC: pas.

STYRACACEAE

Halesia carolina L.
DR: mbm, pd, po.

OLEACEAE

Fraxinus americana L.
DB: mbm; DR: mbm.

Fraxinus pennsylvanica Marsh
D9: mbm.

GENTIANACEAE

Frasera caroliniensis Walt.
D9: og.
Gentiana flavida Gray
D9: og.
Gentiana quinquefolia L.
DR: mbm.
Sabatia angularis (L.) Pursh
CH: pd; D9: mbm, og; N: pd; DR: pd; LC: mbm.
Obolaria virginica L.
D9: mbm; LC: mbm.

ASCLEPIADACEAE

Asclepias exaltata (L.) Muhl.
CH: os.
Asclepias pulchra Ehrh.
F: s.
Asclepias quadrifolia Jacq.
DB: po; DR: mbm.
Asclepias syriaca L.
F: mbm, pd, s.
Asclepias tuberosa L.
DB: mbm; HB: pd; N: og.
Asclepias verticillata L.
DB: po; F: pd; N: og; D9: og; LC: pa.

CONVOLVULACEAE

Cuscuta Gronovii Willd.
DR: mbm, pd; HB: s; NG: pd.
* *Ipomoea purpurea* (L.) Roth.
DR: pd; HB: pd, s.
Ipomoea lacunosa L.
HB: s.

POLEMONIACEAE

Phlox carolina L.
DB: po; D9: mbm; NG: pas, pd; DR: mbm; LC: mbm, pa.
Phlox ovata L.
DB: po.
Phlox stolonifera Sims
CH: mbm; DB: mbm.

HYDROPHYLLACEAE

Hydrophyllum canadense L.
DR: mbm.

BORAGINACEAE

* *Cynoglossum officinale* L.
NG: pas, pd.
Cynoglossum virginicum L.
CH: os; DR: pd; D9: mbm; DB: po.
Myosotis laxa Lehm.
F: s.

VERBENACEAE

Verbena urticaefolia L.
D9: mbm; F: pd; HB: pd.

LABIATAE

Collinsonia canadensis L.
DR: mbm; F: mbm; LC: mbm.
Hedeoma pulegioides (L.) Pers.
CC: pas, pd; DR: pd; N: og; CH: pa; LC: mbm; NG: pd.
Lycopus uniflorus Michx.
F: s.
Lycopus virginicus L.
CC: pas, pd; F: s; N: s; DB: po; HB: s; DR: pd; LC: mbm
* *Mentha piperita* L.
DR: pd; F: s; HB: s.
Monarda clinopodia L.
NG: pd.
Monarda didyma L.
DB: po.
Monarda fistulosa L.
CH: mbm; DR: pd; D9: mbm.
Monarda mollis L.
D9: mbm.
* *Nepeta Cataria* L.
DR: pd; F: pd, s; NG: pd.
* *Nepeta hederacea* (L.) Trevisan
CH: os; F: s; NG: pas, pd; DR: pd.
* *Perilla frutescens* (L.) Britton
LC: mbm.
* *Prunella vulgaris* L.
CH: mbm, os, pa; D9: og; HB: pa, s; DR: pd; F: mbm, pd, s; NG: pas, pd.
Pycnanthemum incanum (L.) Michx.
D9: mbm.

Pycanthemum montanum Michx.
DR: mbm.
Pycnanthemum pycnanthemoides (Leavenw.) Fernald
CC: pas; F: pd; NG: pd; DR: pd; HB: s; D9: mbm; LC: mbm, po.
Salvia lyrata L.
CH: mbm; DR: pd; D9: mbm, og.
Scutellaria incana Muhl.
CC: pas; D9: mbm.
Scutellaria lateriflora L.
F: s.
Scutellaria pilosa Michx.
CH: os; D9: mbm, og; N: og, os; DB: pa.
Trichostema dichotomum L.
D9: mbm.

SOLANACEAE

**Datura Stramonium* L.
CC: pd; DB: mbm; DR: pd.
**Lycopersicon esculentum* Mill.
N: os.
**Nicandra Physalodes* (L.) Pers.
DB: mbm.
Physalis ambigua (A. Gray) Britton ?
LC: pa.
Physalis angulata L. ?
HB: pd.
Physalis intermedia Rydb. ?
CH: mbm; LC: mbm.
Physalis pubescens L. ?
DR: pd.
Solanum carolinense L.
CC: pas; DR: pd; HB: pa; CH: mbm, pa; D9: og; N: og; DB: pa; F: pd, s; NG: pas, pd.
Solanum nigrum L.
NG: pd.

SCROPHULARIACEAE

Castilleja coccinea (L.) Spreng.
NG: pas, pd.
Gerardia laevigata Raf.
DR: mbm; LC: mbm, po; N: os; HB: po.
Gerardia purpurea L.
F: s.
Gerardia tenuifolia Vahl.
DR: mbm, pd; D9: mbm; NG: pd.

Melampyrum lineare Desr.
F: mbm; N: os.
Mimulus ringens L.
F: s; HB: s.
Penstemon canescens Britton
DR: pd.
Scrophularia marilandica L.
CC: pas.
**Verbascum Blattaria* L.
CC: pd; F: pd.
**Verbascum Thapsus* L.
CC: pas, pd; D9: og; LC: po; CH: mbm; F: pd, s; N: og; DR: pd; HB: pd; NG: pas, pd.
Veronica arvensis L.
DR: pd; LC: po; NG: pas, pd; HB: s; N: og.
Veronica officinalis L.
DB: mbm, po; F: mbm, pd; N: og, os; DR: pd; HB: pd, po; NG: pas, pd.
Veronica peregrina L.
DR: pd.
Veronica serpyllifolia L.
CH: mbm; NG: pas.

OROBANCHACEAE

Conopholis americana (L.f.) Wallr.
DB: mbm, po; DR: mbm; LC: mbm.
Epifagus virginiana (L.) Bart.
D9: mbm; F: mbm.

ACANTHACEAE

Ruellia humilis Nutt.
CC: pd.

PLANTAGINACEAE

Plantago aristata Michx.
CH: mbm; F: pd; NG: pas.
**Plantago lanceolata* L.
CC: pas, pd; DR: pd; N: og; CH: mbm; F: s; NG: pas, pd; DB: mbm; HB: pa, pd.
Plantago Rugelii Dcne.
CC: pas; DR: pd; HB: pd; DB: mbm; F: s; N: s.
Plantago virginica L.
CC: pas, pd.

RUBIACEAE

Diodia teres Walt.
CC: pas, pd; DR: pd; LC: mbm; CH: mbm.

Galium asprellum Michx.
F: s.
Galium circaezans Michx.
CC: pas; DR: mbm, pd; LC: mbm; CH: os; D9: mbm, og; N: os; DB: mbm; HB: pd.
Galium latifolium Michx.
NG: pd.
Galium pilosum Ait.
D9: mbm, og; NG: pd.
Galium triflorum Michx.
DB: mbm; HB: pd, po, s; NG: pd; F: mbm; LC: mbm.
Houstonia caerulea L.
DB: mbm, pa, po; D9: og; F: mbm, pd, s.
Houstonia purpurea L.
CC: pas, pd; D9: mbm, og; N: os; CH: mbm, pa, os; HB: pa, po; NG: pas, pd; DR: mbm, pd; LC: mbm, pa, po.
Houstonia purpurea L. var. *pubescens* Britton
D9: og.
Houstonia serpyllifolia Michx.
DR: mbm, pd.
Mitchella repens L.
DB: mbm; LC: mbm, pa, po.

CAPRIFOLIACEAE

**Lonicera japonica* Thunb.
CC: pas.
Sambucus canadensis L.
CC: pas; DR: pd; LC: mbm; CH: mbm; F: pd, s; NG: pd; DB: mbm; HB: s.
Sambucus pubens Michx.
DB: mbm; HB: s; NG: pd.
Symphoricarpos orbiculatus Moench.
D9: mbm; F: s.
Viburnum acerifolium L.
CH: os; DR: mbm; F: mbm.
Viburnum prunifolium L.
HB: pa, po.

CUCURBITACEAE

Sicyos angulatus L.
F: mbm.

CAMPANULACEAE

Campanula americana L.
DR: mbm.
Campanula flexuosa Michx.

CH: mbm, pa, os; F: mbm, pd; NG: pd; DB: mbm; LC: mbm, pa, po; DR: pd; N: og.

Specularia perfoliata (L.) A. DC.

CC: pas, pd; D9: og; N: og; CH: pa; F: pd, s; NG: pas, pd; DR: pd; HB: pa, po, s.

LOBELIACEAE

Lobelia cardinalis L.

DR: mbm, pd; HB: s; N: s.

Lobelia inflata L.

CC: pas; HB: pd; N: og; DB: mbm; LC: mbm.

Lobelia puberula Michx.

CH: pa; D9: og; LC: mbm; DR: mbm.

Lobelia siphilitica L.

DB: mbm; D9: mbm; HB: pd, s; DR: pd; F: s.

Lobelia spicata Lam.

F: mbm, pd.

Lobelia spicata Lam. var. *campanulata* McVaugh

NG: pd.

Lobelia spicata Lam. var. *hirtella* Gray

DB: pa.

Lobelia spicata Lam. var. *leptostachya* (A. DC.) Mackenzie & Bush

D9: og.

Lobelia spicata Lam. var. *originalis* McVaugh

D9: og.

COMPOSITAE

Achillea Millefolium L.

CC: pd; DR: pd; N: og, s; CH: mbm; F: pd, s; Ng: pas, pd; DB: mbm; HB: pa, pd, po, s.

Actinomeris alternifolia DC.

CC: pas; DB: po; D9: mbm.

Ambrosia elatior L.

CC: pas; DR: po; HB: pa, pd, s; CH: mbm, pa; D9: mbm; N: og, s; DB: mbm, po; F: pd, s.

Ambrosia trifida L.

CC: pas; DR: pd; HB: s; DB: po; F: s.

Antennaria plantaginifolia (L.) Richards

CC: pas; NG: pd.

Antennaria solitaria Rydb.

LC: po.

Arctium minus L.

DR: pd; F: s; NG: pd.

Aster Curtisii T. & G.

F: mbm.

Aster divaricatus L.
CH: os; F: mbm, pd, s; N: os; DR: mbm, pd; LC: mbm; NG: pd.
Aster dumosus L.
D9: mbm; LC: pa.
Aster oblongifolius Nutt.
NG: pd.
Aster paniculatus L.
HB: s; N: og.
Aster patens Ait.
DB: mbm, pa, po; HB: pa; N: og.
Aster prenanthoides Muhl.
F: s.
Aster puniceus L.
HB: s.
Aster sagittifolius Willd.
DR: mbm.
Aster undulatus L.
DB: po; DR: mbm; HB: pd.
Bidens bipinnata L.
CC: pas; F: pd; N: og; DR: pd; HB: pd.
Bidens comosa (A. Gray) Wiegand
F: s.
Bidens frondosa L.
HB: s.
Brachychaeta sphacelata (Raf.) Britton
CC: pas.
Cacalia atriplicifolia L.
DR: mbm; F: pd, s; NG: pas, pd.
**Chrysanthemum Leucanthemum* L.
CC: pas, pd; DR: mbm, pd; HB: pd, po, s; CH: mbm; D9: mbm; N: og, os, s; DB: mbm, pa; F: pd, s.
Chrysopsis graminifolia (Michx.) Nutt.
LC: pa.
Chrysopsis mariana (L.) Nutt.
CH: mbm, pa; D9: og; LC: mbm, pa, po; DR: pd; HB: pa, po; NG: pd.
Cichorium Intybus L.
HB: po, s.
**Cirsium lanceolatum* (L.) Hill
DB: po; F: pd; N: og; DR: pd; HB: pd; NG: pd.
Chrysogonum virginianum L.
LC: po.
Coreopsis major Walt.
CH: pa; D9: og; NG: pas; DB: pa, po; HB: pa, po; DR: mbm; LC: pa, po.
**Crepis tectorum* L.
F: s.

Elephantopus carolinianus Willd.
CC: pas.
Elephantopus tomentosus L.
LC: po.
Erechtites hieracifolia (L.) Raf.
DB: mbm, po; DR: pd; HB: pd.
Erigeron annuus (L.) Pers.
CC: pas; D9: mbm; HB: po; DR: pd; F: s.
Erigeron canadensis L.
CC: pas, pd; F: pd; N: og, s; CH: po; HB: po; DR: pd; LC: mbm.
Erigeron pulchellus Michx.
CC: pas; DR: pd; LC: mbm, po; CH: mbm, pa; D9: mbm; N: og; DB: po; F: pd; NG: pas,pd.
Erigeron ramosus (Walt.) B. S. P.
CC: pas, pd; D9: mbm, og; N: og, s; CH: mbm, pa, os; F: mbm, pd, s; NG: pas, pd; DB: mbm, pa, po; HB: pa, pd, po, s; DR: mbm, pd; LC: mbm.
Eupatorium album L.
CH: mbm; D9: mbm.
Eupatorium aromaticum L.
CC: pas; LC: pa; NG: pd; D9: og; N: og, os.
Eupatorium latidens Small
N: pd.
Eupatorium leucolepis T. & G.
CH: os.
Eupatorium maculatum L.
CC: pas; DB: po; HB: s; CH: mbm; D9: mbm; N: s.
Eupatorium perfoliatum L.
DB: po; F: pd, s; HB: s; DR: pd.
Eupatorium sessilifolium L.
CH: os.
Eupatorium trifoliatum L.
DR: mbm; D9: og; LC: mbm.
Eupatorium urticaefolium Reichard
CH: mbm; DR: mbm, pd; F: mbm, pd, s; DB: po; D9: mbm, og; LC: mbm.
**Galinsoga ciliata* (Raf.) Blake
DB: mbm; D9: mbm; N: og, s; DR: pd.
Gnaphalium obtusifolium L.
CC: pas; DR: pd; HB: pd, po; CH: mbm, pa; D9: mbm, og; N: og; DB: mbm, pa; F: pd.
Gnaphalium purpureum L.
CC: pas, pd; DR: pd; HB: pd; CH: mbm; F: pd; NG: pas.
Helenium autumnale L.
CH: mbm; F: pd, s; N: s; DR: pd; HB: s.
Helenium nudiflorum Nutt.
HB: pd.

Helianthus atrorubens L.
CH: mbm; HB: po; LC: mbm, pa, po; DR: mbm.
Helianthus glaucus Small
CH: pa; D9: mbm, og; LC: pa, po; DR: mbm.
Helianthus tuberosus L.
HB: s.
Hieracium Greenii Porter & Britton
DR: pd; N: os; NG: pas.
Hieracium Gronovii L.
D9: mbm; HB: pd; N: og.
Hieracium paniculatum L.
HB: po.
Hieracium scabrum Michx.
DB: mbm; HB: pa; N: og.
Hieracium venosum L.
CH: pa, os; DR: mbm; LC: pa, po; DB: pa; F: pd; NG: pas, pd.
Krigia virginica (L.) Willd.
CC: pas, pd; DR: pd; N: og.
Lactuca canadensis L.
HB: pd.
Lactuca sagittifolia Ell.
DB: po; HB: po, s.
Lactuca saligna L.
DB: mbm; F: pd; HB: pd.
**Lactuca scariola* L. var, *integrata* Gren. & Godr.
HB: pd; N: og.
Lactuca spicata (Lam.) Hitchc.
DB: po; N: og; NG: pd; HB: pd, s.
Lactuca spicata (Lam.) Hitchc. var. *integrifolia* (Gray) Britton
DR: mbm; HB: s.
Lactuca villosa Jacq.
HB: s.
Liatris graminifolia (Walt.) Willd.
LC: pa.
Liatris graminifolia (Walt.) Willd. var. *Smallii* Gaiser
LC: po.
Liatris spicata (L.) Willd.
CH: pa; DR: mbm, po; LC: pa.
Prenanthes altissima L.
DB: po; DR: mbm; D9: mbm.
Pyrrhopappus carolinianus (Walt.) DC.
HB: s.
Rudbeckia hirta L.
DR: mbm; F: mbm, pd; LC: mbm; D9: mbm; HB: pd; NG: pas, pd.

Rudbeckia laciniata L.
CC: pas; DR: pd; HB: s; DB: mbm, po; F: s.
Senecio aureus L.
DB: mbm; F: s; NG: pd; DR: pd; HB: s.
Senecio Smallii Britton
CC: pas, pd; D9: og; NG: pas, pd; CH: mbm, pa, os; F: pd; DR: pd; LC: po.
Sericocarpus asteroides (L.) B. S. P.
CH: pa, os. HB: pa, po; LC: mbm, pa, po; DR: mbm.
Silphium Asteriscus L.
D9: og.
Solidago bicolor L.
NG: pd.
Solidago Boottii Hook.
CH: pa; HB: po; NG: pd; DR: mbm; LC: mbm, po; F: s: N: os.
Solidago canadensis L.
CH: mbm; D9: og; HB: pd, s; DB: po; F: pd, s; N: s.
Solidago Curtisii T. & G.
DR: mbm; F: mbm.
Solidago erecta Pursh
D9: og; HB: pa, po, s; LC: mbm.
Solidago flexicaulis L.
DR: mbm.
Solidago nemoralis Ait.
CH: pa, po; D9: mbm, og; NG: pd; DB: po; HB: pa, pd; DR: pd; N: og, os.
Solidago odora Ait.
CC: pas; LC: pa, po.
Solidago rigida L.
F: s.
Solidago serotina Ait.
CC: pas; D9: og; NG: pd; DR: pd.
Solidago ulmifolia Muhl.
DB: po.
**Taraxacum officinale* Weber
CC: pas; DR: pd; N: og; CH: mbm; F: pd; NG: pas.
Verbesina occidentalis (L.f.) Walt.
NG: pd.
Vernonia glauca (L.) Britton
F: mbm, pd; HB: pd; N: og.
Vernonia noveboracensis (L.) Willd.
CC: pas; F: s; N: s; CH: mbm; HB: s; NG: pd; DR: pd; LC: mbm.
Xanthium canadensis Mill. ?
HB: s; N: s.

SUMMARY

Ten high-grade olivine deposits in North Carolina and Georgia were studied. Twelve others in the two states were visited during August 1947.

The deposits are characterized by a great number of species but by very few individuals of any one species. 750 species and varieties, which are a representative cross-section of the typical mountain flora of North Carolina, were found on the ten deposits. 3475 specimens were collected and studied. Most of these are deposited in the herbarium of the University of North Carolina.

The communities described are maple-beech-birch-magnolia, pine-andropogon, pine-oak, oak-grass, oak-shrub, grass-weed, alder-sedge-smartweed, and grass-weed-oak. Soil moisture relations are the primary controlling factors in community succession and distribution. Moisture and soil acidity or alkalinity are the controlling factors in species distribution on the deposits.

No correlation between species and mineral distribution on the deposits was discovered. No endemics were found on the deposits. Several species were found localized on the deposits. These were not observed in the areas immediately surrounding the deposits but do occur elsewhere in the state.

Ruellia humilis Nutt., *Eupatorium latidens* Small, and *Arenaria patula* Michx. are reported as new to North Carolina. *Clematis Beadlei* (Small) Erickson is reported as new to Georgia.

Plants found on the olivine deposits that normally grow in calcareous regions are *Camptosorus rhizophyllus*, *Ruellia humilis*, *Arenaria patula*, *Frasera caroliniensis*, and *Carex plantaginea*.

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LITERATURE CITED

FERNALD, M. L. 1907. The Soil Preferences of Certain Alpine and Subalpine Plants. Rhodora **9:** 149–194.

GORDON, A., AND LIPMAN, C. B. 1930. Why Are Serpentine and Other Magnesian Soils Infertile? Soil Sci. **22:** 291–302.

HARSHBERGER, JOHN R. 1903. An Ecological Study of Serpentine Barrens of Pennsylvania. Science **18:** 309–313.

HUNTER, C. E. 1941. Forsterite Olivine Deposits of North Carolina and Georgia. N. C. Dept. of Conser. and Devel. Bull. No. 41, Raleigh, N. C.

HURLBUT, C. S. 1941. Dana's Manual of Mineralogy, 15th Ed. John Wiley and Sons Inc., New York.

MASON, H. L. 1946. The Edaphic Factor in Narrow Endemism. I. The Nature of Environmental Influences. Madrono **8:** 209–226.

——— 1946. The Edaphic Factor in Narrow Endemism. II. The Geographic Occurrence of Plants of Highly Restricted Patterns of Distribution. Madrono **8:** 241–258.

MERRILL, G. P. 1921. A Treatise on Rocks, Rock-weathering, and Soils. The Macmillan Co., New York.

PENNELL, FRANCIS. 1910. Flora of the Conowingo Barrens of Southeastern Pennsylvania. Proc. Acad. Nat. Sci. of Phila. **62:** 541–585.

——— 1912. Further Notes on the Flora of the Conowingo or Serpentine Barrens of Southeastern Pennsylvania. Proc. Acad. Nat. Sci. of Phila. **64:** 520–542.

PRATT, J. H., AND LEWIS, J. V. 1905. Corundum and the Peridotites of Western North Carolina. N. C. Geol. Survey Vol. I. Raleigh, N. C.

ROBINSON, B. L., AND FERNALD, M. L. 1908. Gray's New Manual of Botany. American Book Co., New York, N. Y.

SCHIMPER, A. F. W. 1903. Plant Geography upon a Physiological Basis. Chapter V. The Soil. Clarendon Press, Oxford, England.

EXPLANATION OF PLATE 8

Top Photograph: CANE CREEK DEPOSIT. Boulders Cover Slopes of Deposits.
Bottom Photograph: BURTON LAKE DEPOSIT. An Example of Oak-Grass Community. One of the Deposits in Georgia visited during August 1947.

PLATE 8

THE GENUS CODIUM IN NORTH CAROLINA

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Durham, North Carolina

Plate 9 and Three Text Figures

Among the larger and more conspicuous of the marine algae inhabiting the shallow coastal waters at Beaufort, North Carolina, the genus *Codium* Stackhouse is well represented during the warmer seasons of the year. It is a green alga belonging to the order Siphonales, and according to Smith (1938) is represented in the warmer seas of the world by forty-five species. Collins (1909) lists nine species for North America, Taylor (1928) reports seven species for Florida and Dry Tortugas and Collins (ibid.) and Hoyt (1920), two species for North Carolina.

The macroscopic appearance of *Codium* in North Carolina resembles a small green rope which is commonly dichotomously branched at somewhat regular intervals. The plants vary from perfectly cylindrical to more or less flattened in the portions where branching occurs. Structurally, it is composed of numerous branching, coenocytic filaments, the inner of which are small in diameter, colorless and interwoven into a central core or "medulla." From these inner filaments arise green club-shaped branches called "utricles" which become compactly arranged in a surface layer or "cortex." The utricles function as photosynthetic organs and bear the reproductive organs.

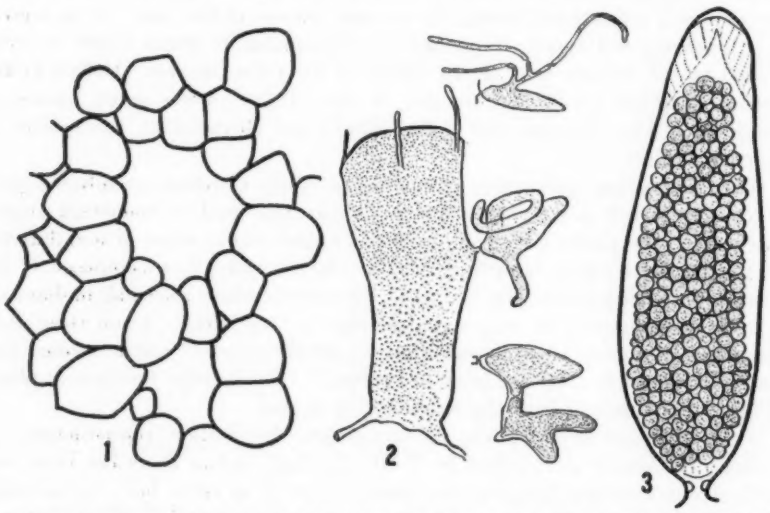
Since little was known about the abundance, distribution, reproduction, and ecology of *Codium* as it occurs in North Carolina, and as there has been some difficulty in distinguishing the two species reported to occur here, an investigation of this alga was commenced in the summer of 1940 and has been continued intermittently up to and through the summer of 1947. Observations have been made on material from Ocracoke to Fort Fisher, but most of the work has been done in the vicinity of Beaufort and Cape Lookout.

The two species of *Codium* reported for Beaufort, North Carolina, are *C. dichotomum* (Huds.) S. F. Gray [reported as *C. tomentosum* (Huds.) Stackh.] and *C. decorticatum* (Woodward) Howe. The specific differences between these two are mainly in the size of the utricles and the habit of the plants (Plate 9, fig. 2). *Codium dichotomum* has smaller utricles ranging from 84 to 200μ (usually 130 to 170μ) in diameter (Collins, 1905; Hoyt, 1920; Schmidt, 1923; and Taylor, 1928) while in *C. decorticatum* they range from 300 to 400μ (Hoyt, 1920; Schmidt, 1923; and Taylor, 1928). In habit, *C. dichotomum* is shorter, with terete branches, and little if at all flattened below the dichotomies; *C. decorticatum* is long and flattened, usually conspicuously so, below the branches.

In discussing the material of *Codium* which occurs at Beaufort, Hoyt (ibid., p. 433) stated that while the forms of both species occur here, he had encountered

considerable difficulty in distinquishing the two species in the Beaufort plants because of the wide variation in each form and the many intergradations between them. Other investigators seem to have experienced similar difficulties with these two species in other localities (Howe, 1911).

In attempting to identify the above species reported to occur here, the author experienced the same difficulty that Hoyt did, that there was too much intergrading of forms to make possible the separation of the two species on habit alone. Therefore, careful and extensive measurements of utricles were undertaken. This revealed that the utricles also have a wide size variation (Text Fig. 1) but that the average for each plant is much larger than in *C. dichotomum*.



Codium decorticatum. Fig. 1. Surface view of portion of a thallus showing giant utricles dispersed among smaller utricles. ×25. Fig. 2. A utricle with one attached propagule and two detached propagules. ×55. Fig. 3. Macrogametangium with macrogametes enclosed. ×225.

It was not unusual to find utricles as large as 575μ in diameter. Furthermore, no correlation of size of utricles could be established between the different forms that occur in the summer and fall. Plants with typical *C. dichotomum* habit had the same size utricles as those of *C. decorticatum*. However, early spring forms of juvenile plants not only had the habit of *C. dichotomum*, but, in some of them, the utricles had the size range for this species, but when growth of these juvenile forms was carefully followed their utricles soon attained the average size of those of *C. decorticatum*. The specimens on which Hoyt based his report were also examined. In comparing the size of utricles in the specimens which he assigned respectively to the two species, no appreciable differences were found in the size of utricles, and all of them fall within the range of those of *C. decorticatum*.

From the above observations it was concluded that upon the basis of size of utricles, which is one of the fundamental characters used in separating the different species of *Codium*, all forms which occur in the Beaufort estuary must be assigned to *C. decorticatum*.

To check the above conclusion, further study was made upon the habit of the plants. A large number of specimens from different locations were examined. The result of these observations shows that a complete series of intergrading forms exists between the two extreme forms. Further observations also indicate that the *C. dichotomum* form is only a juvenile or depauperate form of *C. decorticatum*. It is interesting to note that Agardh, in describing *C. elongatum* in 1822 (now *C. decorticatum*), stated that the juvenile form resembles *C. tomentosum* (now *C. dichotomum*). The most conclusive evidence, however, that the two forms belong to the same species, is the fact that both forms may occur on the same thallus.

Additional evidence that the two forms found here are genetically the same was obtained when tips of both forms were grown under identical, favorable, environmental conditions. It was assumed that they would develop into the same kind of plants if they belonged to the same species, or they would remain unlike if they represented different species. Ninety tips (Plate 9, fig. 3) of each of these two forms respectively were collected and tied to bricks (Plate 9, fig. 4). An effort was made to collect plants from a variety of habitats. After thirty-two days of growth, both sets of tips had tripled in size and had become the long flattened form of *C. decorticatum* (Plate 9, fig. 5). This experiment furnished further evidence that all of the forms are those of *C. decorticatum*, and that the form of the plants vary with age and with environmental conditions. Plants growing under favorable environmental conditions become long, flattened, and regularly dichotomously branched. Juvenile, early spring plants and plants growing under poor light conditions develop into short, much-branched thalli, which frequently do not become flattened.

On the basis of the above evidence, it is definitely concluded that all of the plants of *Codium* growing in the Beaufort estuary must be assigned to *C. decorticatum* and that *C. dichotomum* does not occur here. Below is a description of *C. decorticatum* as it is represented at Beaufort, North Carolina:

Plants cylindrical, varying from short, more or less irregularly dichotomously branched in stunted and young plants to long and regularly dichotomously branched in large plants which are distinctly flattened, the flattening becoming widest below the branches, where it sometimes reaches nine centimeters; attached by a Vaucheria-like system of colorless rhizoids to firm objects with rough surfaces to a mean depth of twenty-five inches below mean low tide level. Utricles obovate-clavate, with a truncate apex, not thickened or mucronate at apex, 300 to 570μ in diameter and four to six times as long as the greatest diameter. Plants strictly dioecious. Sporangia (or gametangia) lanceolate-ovate, 230 to 270μ long by 60 to 100μ at the greatest diameter, when mature with gelatin inside their tips and bases to a mean depth of 40μ at the tip, and 25μ at the base; sporangia of two kinds, equal in size: microsporangia with mature microgametes dark yellow, the gametes small (3–4 x 3μ after discharge); macrosporangia with

mature macrogametes dark green, the gametes large (17–18 x 11–12μ after discharge).

Another species, *C. isthmocladum* Vickers, has occasionally been found drifted ashore in the vicinity of Beaufort. The fresh condition of these plants indicates that they could not have come very far since plants of *Codium* soon degenerate when they become detached and drift. It was not surprising, therefore, to find it attached on the offshore jetty at Cape Lookout. Collections of it at this locality were made in the fall of 1946 and again in the summer of 1947. Here it grew associated with *C. decorticatum*. These two species are not always easily distinguished macroscopically, especially when growing together as young plants and before *C. decorticatum* has developed its characteristic flattening. Microscopic examination of the utricles, however, reveals that the material of *Codium* at Cape Lookout consists of two species. This conclusion is based on the difference in size of utricles and the thickening of the wall of the apex of the utricles. The specimens of *C. isthmocladum* from Cape Lookout have relatively small utricles (250–300μ) in which the outer wall is distinctly thickened at the tip. Also the branches are often constricted at their bases which is not true of *C. decorticatum*. The absence of *C. isthmocladum* in the Beaufort estuary and its presence at Cape Lookout, only 12 miles apart, indicate that environmental conditions of the inshore waters of Beaufort are not suitable for its attachment and growth.

REPRODUCTION

Thuret (1850) seems to have been the first one to see the "gametangia" and biflagellate gametes in *Codium*. Berthold (1880) observed that reproduction did not occur when the male and female plants were grown separately. In September 1896, Oltmanns (1904) saw fusion of anisogametes, which took place between twelve and one o'clock at night. He was able to catch zygotes on glass slides which were placed at the bottom of a *Codium* culture and to observe their germination. In 1925 Miss M. M. Williams—working on *C. dichotomum* in Sydney, Australia—first described meiosis in *Codium*. She found that this took place in the formation of gametes and, therefore, concluded that the plants must be diploid. Previously it had been generally believed that *Codium* was haploid, i.e. a gametophyte, because it produces gametes. This discovery made necessary a change in the terminology of the reproductive structures. The structures which were formerly called "gametangia" should, therefore, be considered as "sporangia."

The principal method of reproduction in *Codium* is sexual. However, reproduction by fragmentation of the thallus is no doubt possible; but, since some time is required for fragments to produce rhizoidal anchorage organs, this method can hardly be of much importance, since fragments seldom remain stationary in moving water long enough to become attached. Asexual reproduction by detachable propagules which appear on the utricles and are either modified branches or immature sporangia have been reported in some species (Schmidt, 1923;

Fritsch, 1935). In the Beaufort plants of *C. decorticatum* such propagules are common in the spring and replace sexual reproduction at this time (Text Fig. 2). However, in summer, propagules have never been encountered, although hundreds of specimens from a variety of localities have been examined. Apparently propagules develop only during periods of low temperature when sporangia do not reach maturity. Functional gametangia are produced during summer and fall when water temperatures are high.

Periodic examination of sporangia indicates that development and discharge of gametes in *C. decorticatum* in the Beaufort estuary is directly correlated with tides. Sporangia may be found at all times in summer, but mature gametangia (i.e. sporangia which have become gametangia) are found only monthly at periods approaching spring tides. Gametes are discharged over a period of two or three days. Discharge takes place by day or night after low of spring tide. Plants brought into the laboratory during the period when gametes are being discharged can be separated into two groups: those with mature gametangia dark golden, or male plants; and those with mature gametangia dark green, or female plants. Since no plants have been observed with both kinds of gametangia it must be concluded that *C. decorticatum* at Beaufort is dioecious. Gamete discharge takes place through the tip of the gametangium in a manner similar to that described by Smith (1938) for *C. fragile* (Suring.) Hariot. A terminal plug of gelatin is shot out by an explosive force and the gametes move out through an apical pore of the gametangium and through a duct in the middle of the gelatin mass usually in single file. While passing through this pore and canal the gametes become much attenuated, but as soon as they are discharged they resume their normal shape. Gametes accumulate above the extruded mass of gelatin after discharge and remain stationary for about 60 seconds before becoming motile. Mrs. Longest (1946), of the University of North Carolina, using the Löffler staining technique on living material from this investigation, found that the two flagella of the microgamete of this species are of the same type as those reported for other green algae. Discharge of gametes in *C. fragile* takes place when plants are flooded after a period of intertidal exposure (Smith, 1938). *Codium decorticatum*, however, is not an intertidal species at Beaufort, but the tips of some of the plants are exposed during extremely low tides (Plate 9, fig. 1). Consequently, in *C. decorticatum* at Beaufort exposure is probably not a factor with which gamete discharge can be correlated.

From one to three sporangia are borne on each utricle, and sporangia of different ages may occur on the same utricle. There seems to be little or no localization on the plants in the production of sporangia, except that they are usually more numerous just below the branches. Microsporangia and macrosporangia in the Beaufort material of *C. decorticatum* are of equal shape and size (Text Fig. 3). According to Tilden (1935), in reporting on the cytological work of Williams (1925), the microsporangia are smaller than the macrosporangia in *C. dichotomum*. This is questionable since it is evident from the illustrations in Williams' paper that she worked with *C. fragile* instead of *C. dichotomum*, as was pointed out by Schmidt (1923). Went (1889) states that in monoecious species

the microsporangia appear about the time the macrosporangia are mature. Schmidt, however, reports that they develop simultaneously. In the Beaufort plants there seems to be a parallel development, and well developed sporangia may be found at any time throughout the summer, but microgametangia cannot be distinquished from macrogametangia until they are ripe and about ready for discharge.

GROWTH

Growth in *Codium* takes place by the addition of new utricles and by their enlargement. These are formed at the tips (apical growth) and also between preexisting utricles (intercalary growth). From the base of each utricle several branches arise. Some grow into the "medulla," while some grow lengthwise between the "cortex" and the "medulla," and sooner or later curve outward and become dilated to form the new utricles.

Inasmuch as mature plants differ in general appearance from young plants an experiment was made to determine how much effect intercalary growth has on the general form of the thallus. Several young plants (typical *C. dichotomum* forms) were used in this experiment. Strings were tied around the fronds one centimeter apart from the place of attachment to the tips. After a month of growth (July 14 to August 15) the plants gave some interesting results. The average plant showed an increase in length of 37 per cent. Growth took place throughout the length of the plant with considerably more growth in the upper portions of the thallus. In most specimens the upper fifth of the thallus grew as much as the remainder of the plant, with considerable apical growth. In 32 days of growth, 90 tips of the *C. dichotomum* form grew from 3–5 to 10–18 cm. in length per plant; while 90 large tips of the *C. decorticatum* form (except those that were eaten back by natural enemies) grew from 5–10 to 20–28 cm. in length, and showed considerable flattening. From the above evidence one would conclude that intercalary growth is largely responsible for the change of a plant from the *C. dichotomum* form to the large flattened form characteristic of *C. decorticatum*.

Regeneration from broken ends of the thallus is frequent and produces numerous small branches. Twelve large plants of the *C. decorticatum* form were trimmed back to within an inch of the shell on which they were attached. After three weeks of growth many small branches were regenerated, each of which grew into the common juvenile *C. dichotomum* form.

DISTRIBUTION

Codium decorticatum has a wide general distribution. According to Hoyt (1920) it is found from North Carolina to Florida; West Indies; Lower California, Mexico; South America; Europe; and Africa. As far as is known it reaches its northern limit of distribution on the eastern coast of North America at Ocracoke, North Carolina, where it was collected in the summer of 1946. It is present the year around in the Beaufort estuary, on the jetty at Cape Lookout, and on the seawall at Fort Fisher. However, the plants begin to diminish in size in the

middle of fall and by winter are represented by small stubs or cushions which could easily be overlooked if they were not marked for observation on the substrata on which they are attached.

Apparently temperature is the principal factor determining the northern distribution of *C. decorticatum* on the east coast of the United States. Charts of thermograph records show that warm masses of water are abruptly broken off from Cape Hatteras (Church, 1936) where the annual range of temperature is 20 degrees C. The annual range of temperature of the sea at Beaufort is also 20 degrees C., but the summer temperature is warmer than the coastal area north of Cape Hatteras. As far as is known, North Carolina is the northern limit of range for many tropical algae such as *Codium*, *Dictyota*, and *Padina*. By more thorough collecting some of these species may be found at points north of North Carolina, but this is unlikely, because these stenothermal tropical species may not be able to persist under the eurythermal conditions found in areas north of North Carolina. According to Setchell (1915), temperature plays a very important part in the distribution of marine algae.

A study of the physical factors in the general distribution of *C. decorticatum* along the east coast of the United States indicates that salinity is not a limiting factor in its northern distribution, since the same salinity prevails further north where *Codium* has not been reported. However, a study of the local distribution of this species in the Beaufort estuary shows that it disappears in places where salinity is less than half of sea water for periods of two or more days.

Large natural beds of *Codium* found at Beaufort are located on clear sandy shoals (Plate 9, fig. 1). However, scattered plants may be found anywhere they can find suitable places for attachment. They are also abundant on artificial breakwaters. Where they grow on shoals they do not grow in sand but are always attached to parts of shells which project out of the sand. The two most common of these shells furnishing attachment here are *Noetia ponderosa* Say and the pinna shell (*Atrina serrata* Sowerby). *Codium* grows on both the living and dead of these two species. Plants have been found growing on a great variety of objects such as rubber hose, tiling, bricks, concrete, communication cables, wire, and shells of Mollusks. However, two factors seem to determine whether *Codium* will become attached on a given object. The object must be within the range of the vertical distribution of *Codium*, and it must present a rough surface. Smooth, firm objects free of any growth of *Codium* are frequently found in beds of *Codium*. Most oyster shells do not furnish suitable places of attachment.

In order to determine the time necessary for *Codium* to settle and grow to visible proportions, rocks were placed in natural beds of *Codium*. After four weeks, some of the rocks showed small, upright, macroscopic growths. The growth might have been more pronounced if the rocks has been set out just before spring tide, since zygotes appear to be formed monthly just after spring tide.

Codium was never found growing more than 25 inches below mean low tide level in the Beaufort estuary, but at Cape Lookout, where the water is clearer, it was found growing four or more feet below mean low tide level. In the

Beaufort estuary it is strictly a sublittoral species, but on the jetty at Cape Lookout, on the exposed coast, it sometimes occurs in the lower littoral zone during periods of continuous wetting from wave action.

In certain habitats the vertical distribution may be correlated with light factors. Inasmuch as *Codium* is an attached plant it does not show periodic vertical migration as do many plankton. Consequently, light becomes a limiting factor below depths where its quantity and quality are insufficient for the minimum requirements from photosynthesis. The presence of suspensoids and dark material in solution in the water of the Beaufort estuary is variable in time and from place to place. Low photometer readings were correlated with poor or no growth of *Codium* in places where suitable attachment was available.

In the Beaufort vicinity certain sandy shoals offer the best places for the growth of *Codium*. Here the water is clear and light penetration is equivalent to that found in any part of the inlet. Currents in these places do not bring mud or silt, and light penetration is decidedly better. Stunted plants grow in places of low light intensity and they are generally darker green than those which grow under strong light intensity. Plants with a light green color placed in the tanks of running marine water in reduced illumination of the laboratory become dark green in about 18 hours. Observation of the utricles of these plants shows that their chloroplasts have migrated to the apices of the utricles. This would indicate that *Codium* has a mechanism for adjusting itself to changing conditions of light intensity within certain limits. The chloroplasts are dispersed under strong intensities and are concentrated near the surface of the thallus under low intensities.

NATURAL ENEMIES

Of the animals that were observed to feed on the thallus of *Codium*, the "sea hare" (*Tethys protea* Rang.) was the most destructive. Several of these animals were brought into tanks in the laboratory in order to determine approximately how much *Codium* they can consume. Over night one "hare" ate three medium sized plants. Diamondback terrapins, in the breeding pens at the Bureau of Fisheries, Beaufort, North Carolina, consume large quantities of *Codium* and some fishes in marine aquaria there eat it in lesser quantities. Although not as destructive as the "sea hare," a spider crab (*Libinia dubia* Milen-Edwards) and a mollusk (*Fasciolaria tulipa tulipa* L.) were also observed to feed on *Codium*. On several occasions the natural beds of this plant showed indications of excessive grazing, which might indicate that some unobserved swimming animals such as fish also feed on *Codium*.

Grateful acknowledgment is here given to Dr. H. L. Blomquist, Department of Botany, Duke University, who directed much of this work.

SUMMARY

1. The two forms of *Codium* at Beaufort, N. C., which have been referred by earlier investigators to *C. dichotomum* and *C. decorticatum* respectively must be

assigned to the latter species upon the following bases: (a) size of utricles, (b) mature form, (c) both forms occurring on the same thallus, and (d) the experimentally-induced growth forms.

2. From the material examined *C. decorticatum* at Beaufort is dioecious.

3. Growth is both terminal and intercalary and amounts to about 37 per cent during one mid-summer month.

4. There is strong evidence that discharge of gametes is periodic in relation to monthly spring tides.

5. The limit of the northern distribution of *Codium* is determined by a sudden drop in temperature of sea water at most seasons at Cape Hatteras, N. C.

6. Local distribution is determined by the following factors: (a) suitable objects of attachment within its vertical range, (b) degree of turbidity as it affects suspensoids and light penetration, and (c) salinity.

7. Several animals have been observed to be natural enemies of *Codium*.

8. *C. isthmocladum* Vickers is reported for the first time as growing attached in North Carolina waters.

LITERATURE CITED

CHURCH, PHIL E. 1936. Temperatures of the Western North Atlantic from Thermograph Records. U. of Wash. and Woods Hole Ocean. Contrib. No. 121.

FRITSCH, F. E. 1935. The structure and reproduction of algae. Vol. 1. New York. Macmillan Co.

HOYT, W. D. 1920. Marine algae of Beaufort, N. C., and adjacent regions. Bull. (U. S.) Bur. Fisheries **36:** 372–550.

LONGEST, PAULINE M. 1946. Structure of the cilia in *Ectocarpus mitchellae* and *Codium decorticatum*. Jour. E. Mitch. Sci. Soc. **62:** 249–252.

OLTMANNS, D. F. 1904. Morphologie und Biologie der Algen. Jena, Verlag von Gustav Fischer.

SETCHELL, W. A. 1915. The law of temperature connected with the distribution of marine algae. Ann. Missouri Bot. Gard. **2:** 287–305.

SCHMIDT, O. C. 1923. Beiträge zur Kenntnis der *Codium* Stack. Bibliotheca Bot. **23:** Heft **91:** 1–68.

SMITH, G. M. 1938. Cryptogamic Botany. Vol. 1. New York, McGraw-Hill Book Co.

TAYLOR, W. R. 1928. The marine algae of Florida and Dry Tortugas. Papers from the Tortugas Lab. of the Carnegie Inst. of Washington **25:** 1–219.

THURET, G. 1850. Ann. Sci. Nat. Bot. 3rd ser. **14:** 214–260.

TILDEN, J. E. 1935. The algae and their life relations. U. of Minnesota Press, Minneapolis, Minn.

WILLIAMS, M. M. 1925. Contributions to the cytology and phylogeny of the Siphonaceous algae. I. The cytology of the gametangium of *Codium tomentosum* (Stackh.) Proc. Linnean Soc. New South Wales **50:** 98–111.

PLATE 9

Figure 1. Natural bed of *Codium decorticatum* on shallow sand flats located west of Piver's Island in the Beaufort estuary. This photograph was taken at low water mark of the lowest tide of the summer. Normally only the tips of some of the plants are exposed during low of spring tide.

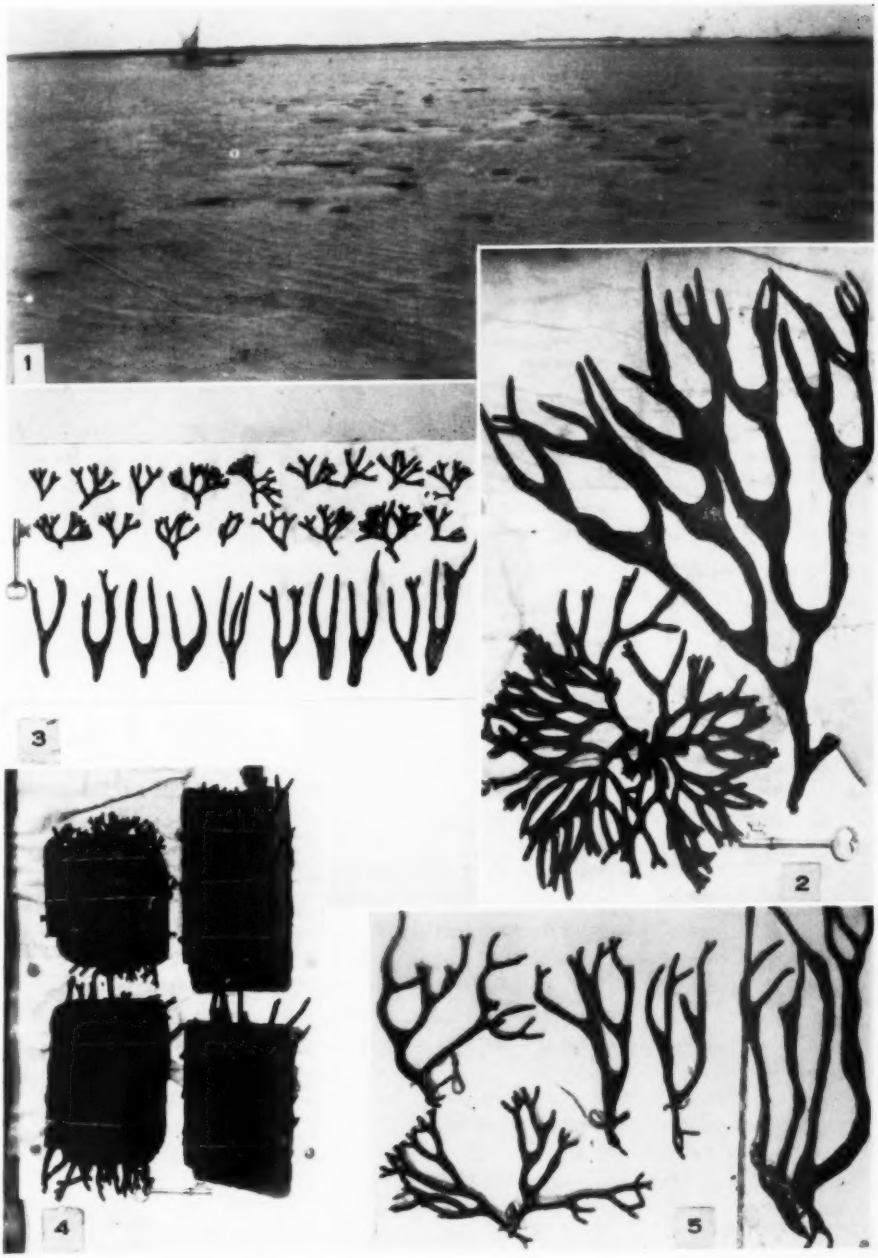
Figure 2. *Codium decorticatum* showing contrasting extreme forms common in the vicinity of Beaufort, North Carolina. The large, flattened form (upper) exhibits the habit of this species. The terete form (lower) has the external habit of *C. dichotomum* and has been incorrectly assigned to this species by phycologists who have worked with the material of *Codium* from this vicinity.

Figure 3. Tips of *Codium*. (above) Densely branched tips (3–5 cm. in length), the *C. dichotomum* form of *C. decorticatum*. (below) Broad, sparingly branched tips (5–10 cm. long) of the flattened form of *C. decorticatum*. Ninety of each of the tips of these two forms were respectively attached to bricks (fig. 4) and grown under favorable conditions to produce flattened forms (fig. 5) of typical *C. decorticatum*.

Figure 4. Tips of *Codium* attached to bricks by string as they appeared at the beginning of 32 days of growth under identical and favorable environmental conditions. (above) the *C. dichotomum* form of *C. decorticatum*. (below) *C. decorticatum*.

Figure 5. Tips of *Codium* after 32 days of growth. (left) The tips of the former *C. dichotomum* form. (right) *C. decorticatum*.

PLATE 9



A CYTOLOGICAL STUDY OF THE EFFECTS OF COLCHICINE, INDOLE-3-ACETIC ACID, POTASSIUM CYANIDE, AND 2,4-D ON PLANT CELLS

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Plates 10–14

This laboratory has been interested for some time in the nature and function of mitochondria in plants. It was hoped that by studying the cytological effects of certain poisons upon plant cells their pathology might yield some evidence as to the function of mitochondria. At least such a study should produce information about the physical changes of protoplasm preceding death, these changes to be expected in both the cytoplasm and the nucleus, which latter body is assumed to direct the ontogeny and metabolism of the cell.

Little is known as to the precise effect of poisons upon protoplasm, or, how chemicals kill, although the physiological reactions of many organisms to various poisons have long been studied. General statements to the effect that the protoplasm of cells when dead is coagulated, precipitated, or lysed give no clues to the specific actions of poisons on the components of living cells. For this reason it was decided to investigate the effect on plant cells of the four chemicals: colchicine, indole-3-acetic acid, potassium cyanide, and 2,4-D, which were chosen partly on account of their availability and common use in botanical research and also because, while all are poisonous in sufficiently high concentrations, their specific modes of action and the responses of plant tissues to them are all different.

The alkaloid colchicine has been used since 1937 as an agent for the production of polyploid plants (Blakeslee and Avery, 1937). It has also been used successfully in killing or inhibiting the growth of plant tumors (Bergner et al., 1940; Dermen and Brown, 1940; Havas, 1937).

Indole-3-acetic acid is a plant growth substance or auxin (Went, 1945), presumably a product of the metabolism of plant cells, having been isolated from them; but when used in other than extremely dilute concentrations it causes a marked growth response, gall or tumor formation, and eventual death of the affected cells. This growth response is used to practical advantage in producing roots on plant cuttings when the concentration is not high enough to be lethal, in producing parthenocarpic fruits, and in preventing fruit-drop.

Potassium cyanide is a powerful respiratory depressant even in very dilute concentrations and causes death as a result of anoxia (James and Hora, 1940).

As for 2,4-D, nothing is known of its physiological effect on plant cells due to the recency of its discovery as an herbicide. It is, however, one of the most effective weed-killers in use today (Grigsby, 1946).

Since the emphasis in this study was to be on the reaction of both mitochondria and chromosomes to the four poisons, much time was spent in preliminary experiments attempting to discover a fixing fluid that would preserve equally well the cytoplasmic and the nuclear constituents of the cell. Heretofore mitochondria have been fixed best by a basic fluid and chromosomes by an acid one. Recent work by Newcomer (1946), indicates that a single fixative adequate for all cell details might be found. The present attempts, however, were unsuccessful, due to some extent perhaps to the variation in permeability of dividing and nondividing cells (Stern, 1946).

MATERIALS AND METHODS

All experiments were carried out on young root tips of *Allium* and *Narcissus* which were grown in Shive's nutrient solution (Miller, 1938) and the bulbs then transferred to the experimental solutions. For colchicine, a 0.2% (0.005M) concentration in tap water was used and root tips cut after exposures of 13, 25, 37, 49, and 61 hours. For the other reagents, all except the 0.05M KCN made up in Shive's nutrient solution, concentrations and times of exposure were as follows:

KCN	0.0065%—25 hours—0.001M
	0.0325%—25 hours—0.005M
	0.325% —25 hours—0.05M
2,4-D	0.01% —25 hours
	0.05% —13 hours
	0.1% —25 hours
Indole-3-acetic acid	0.001% —25 hours

In the monocotyledonous plants used there is a periodicity of cell division which reaches its peak at 11 o'clock, morning and night. In order that advantage could be taken of this maximum division period and a large number of cells be obtained in stages of mitosis, bulbs were put into the reagents at 9 or 10 o'clock, left in for one or more 12-hour periods, and then root tips cut at a subsequent 11 o'clock hour. This schedule was followed for all cuttings.

Standard fixation fluids were used: Zirkle's (Johansen, 1940) for a basic image to show mitochondria and modified Chicago (Chamberlain, 1932) for chromosomes and spindle fibers. The latter was found to cause excessive shrinkage in the root tip cells so was replaced for most of the experiments by weak Flemming (Chamberlain, 1932), which preserved the spindle and chromosomes without distortion of the tissues. Zirkle's fluid was adjusted with the aid of a Macbeth potentiometer to a pH of from 4.4 to 4.8 using 10% KOH, NaOH, and NH_4OH, the last named seeming to give the best results.

Fixation was for 48 hours; then the tissue was washed for 8 to 12 hours, dehydrated in a series of ethyl-tertiary butyl alcohols, embedded in paraffin, and sectioned at 5 microns. Before staining in Heidenhain's hematoxylin, with or without counterstain of Orange G in clove oil, the slides were bleached in 1% $KMnO_4$ and 2.5% oxalic acid and mordanted overnight in 4% iron alum. Lang's (1936) modification of Heidenhain's iron alum, i.e., iron alum acidified with sul-

furic and acetic acids, was found to be superior in keeping properties and intensity of staining to the pure iron alum solution. Clarite was used as the mounting medium.

For purposes of comparison or control, normal root tips were cut at an eleven o'clock hour from bulbs grown in Shive's nutrient solution, fixed in both Zirkle's and weak Flemming killing fluids, dehydrated, embedded, sectioned, and stained as were the experimental tissues.

All pictures were taken with a Leitz "Makam" camera at an original magnification of 900×.

OBSERVATIONS AND DISCUSSION

To avoid repetition, all discussion of chromosomes will be assumed to refer to weak Flemming or Chicago fixations and discussion of mitochondria, vacuoles, or cytoplasm will refer to tissues fixed with Zirkle's fluid. For the specific fixation, hours of exposure, concentration of poison, and plant material used for each illustrative figure, see explanation of plates.

A. *Colchicine:*

The appearance of meristematic cells while under the influence of colchicine is so striking that the term "c-mitosis" has been coined to describe it. The mechanism of this c-mitosis has been investigated and described by Levan, Dermen, and many other writers (see Dermen, 1940, for review of subject). Colchicine apparently lowers the viscosity of the cytoplasm to a point at which spindle fibers cannot be formed (Beams and King, 1938). Consequently, the normal process of chromosome division is halted at metaphase and the sister chromatids appear much contracted, uncoiled, and held together only at the kinetochore, the pairs scattered in a diakinesis-like manner within the cell (Levan, 1938). Eventually this kinetochore connection breaks and as a result the cell now has twice the usual number of chromosomes. If allowed to recover from the drug, this cell will reconstruct its nucleus and on succeeding divisions maintain its tetraploid, or 4n, state. Repetition of this chromosome division unaccompanied by cell division may result in octaploid, 16-ploid, and even 128-ploid cells (Walker, 1938); but cells with high chromosome numbers seldom persist, as such nuclei with difficulty become reconstituted and resume normal mitosis after removal of the drug (Beams and King, 1938). Chromosome doubling will continue as long as the cells are exposed to colchicine of the required concentration. In concentrations above 0.4% (Hawkes, 1942) colchicine is extremely toxic and causes death; also at lower concentrations, when exposure is prolonged and excessive chromosome doubling has occurred, cells are unable to recover. The effectiveness of colchicine in killing plant tumors is thought to be due to a more rapid response of tumor cells than normal cells to the drug and, consequently, excessive polyploidy leading to degeneration in that tissue (Brown, 1939; Dermen and Brown, 1940).

In the present study typical c-mitoses were observed (Figs. 16 and 17). Spindles were lacking and lobed and apparently polyploid nuclei were abundant

in the tissues exposed for 25 hours (Fig. 16). There was not a great deal of division in the tissues given longer treatment; this fact appears to corroborate Levine and Gelber's (1943) observation that the greatest number of metaphase stages occurs at 25 hours after beginning of treatment of the roots with colchicine solution.

Since colchicine is assumed to lower the viscosity or surface tension of the cytoplasm, as is demonstrated by inhibition of spindle formation, its effect on the mitochondria should show whether or not they, too, are sensitive to such changes. Meristem mitochondria were short and rod-like but differed from those of the controls in the tendency to constriction and fragmentation. This was more pronounced in the exposures of 25 hours or longer (Figs. 8 and 9) than in the 13 hour stage (Fig. 7). There was no polymorphism of mitochondria in the older tissues of the root and with few exceptions, regardless of the length of the exposure, they had rounded up into ball-like bodies, some apparently coalescing (Figs. 11–15). Fragmentation was observed in the region of elongation (Fig. 10) after 37 hours of exposure. These activities of the mitochondria: rounding up, coagulating of small globules into larger ones, fragmenting of rods into smaller, rounder bodies, and shortening and thickening of other rods, all indicate a response to lowered surface tension and suggest that mitochondria are sensitive to the viscosity of the surrounding medium.

A secondary effect of colchicine is the swelling occurring in the region of elongation of the young root. These swellings appeared as expected on the roots treated in these experiments. They are not due to polyploidy of the cells, as was once thought; the number of cell rows also is not increased. Each cell, however, seems to have increased in width, thus causing a bulging of the root just above the meristem. According to Hawkes (1942), these cells have roughly the same volume as do cells in a corresponding region in untreated roots, growth occurring in all directions instead of mainly longitudinally.

B. *Indole-3-acetic acid:*

That the concentration of the indole-3-acetic acid used was not strong enough to prevent further growth was demonstrated by replacing the bulb in Shive's nutrient solution after exposure to the reagent and observing the resumation of normal root growth beyond the swollen area. Sub-terminal root swellings are a characteristic result of treatment with indole-3-acetic acid and some other growth substances as well as with colchicine (Levan, 1939). Swellings were conspicuous after 24 hours of exposure to the 0.001% solution. As in the case of the colchicine treatment, this bulging at the region of elongation is not due to an increase in the number of cell rows but to a widening of individual cells of this region. These swellings, strangely enough, do not occur with either colchicine or indole-3-acetic acid treatment if the root tip has been removed (Hawkes, 1942) so are thought to be related in some way to the minute amount of auxin produced naturally in the root tip.

The most startling observation revealed in the study of these tissues was the unusual amount of cell division present, nearly every cell in the meristem being

in some stage of mitosis. Anaphase and telophase stages had normal spindles (Figs. 24 and 25) in contrast to the condition produced by colchicine. These experiments indicate that indole-3-acetic acid when applied from outside the tissue causes a stimulation of cell division that occurs at a slower rate under the regulation, we presume, of the plant's own auxin (Went, 1945). This technic should be useful in treating root tips for chromosome study.

Increased cell division is assumed to indicate increased metabolic activity. If mitochondria are involved in metabolism, they might be expected to become more numerous under this condition. The study of these cells, however, seemed to indicate a general reduction of the mitochondriome in the meristem as compared with that of the control tissues. Occasionally well-fixed cells showed swollen mitochondria and rod-shaped ones that were constricted as if fragmenting (Fig. 18). At the root-swelling above the meristem the mitochondria were mostly vesicular and often clumped (Figs. 21 and 23). The presence of vesiculated mitochondria in this area is not understood but may indicate that these cells have an increased permeability. Farther back in the region of maturation more clumping was observed, with polymorphic structures ranging from attenuated, branched, crooked, and sometimes vesiculated threads to the globular forms (Figs. 19, 20, and 22). The mitochondria, therefore, do not appear to increase with increased cell metabolism and their irregularities resulting from indole-3-acetic acid treatment are not explained by the present study.

C. *KCN:*

A number of workers have investigated the relation of KCN to oxygen consumption in various plants. James and Hora (1940) report that 0.002M KCN reduces respiration in barley leaves about 36%, not, however, preventing recovery in water. At a 0.02M concentration inhibition of oxygen consumption is complete and irreversible. Seifriz (1943) states that 0.01M KCN suppresses respiration 80% in *Physarum* yet does not stop protoplasmic flow so is not strong enough to cause death. The present experiments indicate that a concentration of 0.005M on root tissues of *Allium* does cause death of some cells and that at 0.05M necrosis is extensive. Necrotic cells were observed as first occurring in the meristem of the 0.005M concentration; the plerome appeared to be most resistant to the poison.

Both nuclei and cytoplasm of the tissues exposed to the strongest concentration were extremely difficult to stain. Prolonged mordanting with iron alum did not increase their stainability, nor did a four-day premordanting in $K_2Cr_2O_7$. In the meristem the chromosomes were extremely attenuated and ragged (Figs. 27, 28, and 30), presenting a markedly abnormal appearance faintly reminiscent of the "lampbrush" chromosomes as described by Kodani (1941). The matrix had largely disappeared. Nuclei of resting cells were large and pale, the chromatin content appearing sharply outlined in irregular strands and masses in the absence of stained nuclear lymph (Figs. 28 and 30). Back of the meristem the cells were colorless.

In a study of barley seedlings deprived of oxygen by being grown in an atmos-

phere of nitrogen for four days, Steinitz (1943) reports continuation of mitosis but with such abnormalities as chromosome clumping, sticky anaphase bridges, and extrusion of chromatic material into the cytoplasm. These observations were not corroborated in the present study since mitotic stages could not be identified beyond metaphase and all were poorly stained. Whatever the relationship of the nucleus to cellular respiration, and this study offers no enlightenment upon it, it is interesting to note that Steinitz, in observing effects of anoxia upon the nucleus, did not observe failure of formation of the chromosome matrix such as results from KCN treatment. This indicates that this condition may be due to a secondary effect not associated with anoxia. It would be interesting to see if the gene string were not also affected by KCN if organisms so treated were allowed to recover.

Mitochondria in living cells were extremely abnormal and generally coagulated (Fig. 26), in some cases swollen and in others fragmented (Fig. 29) and almost totally destroyed. None of the typically normal, filamentous types were found. This coagulation and destruction of mitochondria may lend some support to the hypothesis that they are associated with cellular respiration. The reaction of mitochondria to other respiratory-inhibiting substances should be observed. Steinitz, unfortunately for this study, was concerned only with the chromosome and nuclear phenomena of the cell.

D. *2,4-D:*

According to Grigsby (1946), a 0.01% concentration of 2,4-D will kill young poison ivy growth, 0.05% concentration stops pollen production in ragweed, and 0.1% kills ragweed.

The most noticeable effects of 2,4-D in the present study were excessive vacuolation of the cytoplasm in the meristem, a general inhibition of cell division, and the production of c-mitotic metaphases. Very few dividing cells were observed at the 0.05% concentration, and although in tissues exposed to the higher concentration a great number of prophases were seen, no stages beyond metaphase were found and the chromatin itself appeared granular and much disturbed. The metaphase chromosomes had a typical c-mitotic appearance, the chromatids partly separated and pairs scattered in the cell without an observable spindle (Fig. 32). Polyploidy, however, was not evident. Other chemicals, among them acenaphthene, bromonaphthalene (Levan and Ostergren, 1943), and podophyllin (Sullivan and Wechsler, 1947), have been reported to cause c-mitosis, also without causing c-tumors. Perhaps in sufficiently dilute concentration 2,4-D might also produce polyploidy.

Meristem mitochondria in the 0.05% concentration were irregularly swollen and crooked (Fig. 31). In the 0.1% concentration, farther back in the root tissues, they had an especially fragmented appearance (Fig. 33). Death of cells was not observed in concentrations below 0.05%. At this strength, though, some cells of the inner periblem had been killed. At the higher concentration necrosis was more general; the epidermis and upper plerome seemed to be most resistant.

A general description of the morphological appearance of the cell preceding death by 2,4-D would be as follows: the chromatin network of the resting nucleus granular instead of the usual anastomosing threads, the mitotic cycle stopped, cytoplasm excessively vacuolated, and the mitochondria disintegrating and presenting a lysed appearance. Since cellular structure is the basis of cellular function, death apparently results from a general collapse of the morphological constituents of the cell which precludes any adequate description of how 2,4-D kills.

SUMMARY

Colchicine treatment indicates that mitochondria are affected by changes in the viscosity of the protoplasm.

The effect of colchicine upon the nuclear cycle corroborates the findings of previous investigators.

0.001% indole-3-acetic acid causes a phenomenal increase in the number of mitoses in the root tip meristem and the technic should have value in chromosome studies.

The metabolic stimulus of indole-3-acetic acid as indicated by increased cell division does not increase the number of mitochondria per cell.

KCN causes marked diminution of the chromosome matrix resulting in ragged chromosomes and it is suggested that the gene string may be affected. Since this condition has not been reported in studies of respiratory inhibition using nitrogen, the observed effect may be due to causes other than anoxia.

KCN causes a marked loss of staining capacity of cells, which increases with the concentration.

KCN and 2,4-D cause a similar disintegration of the mitochondria preceding death of the cell. No conclusions can be drawn as to the specific cause of this condition.

2,4-D causes inhibition of cell division and the appearance of c-mitoses in the root tip meristem but no polyploidy. This latter condition might be obtained by treatment with a sufficiently dilute concentration of the poison.

This work was done under the direction of Dr. E. H. Newcomer, to whom I wish to express my gratitude.

LITERATURE CITED

BEAMS, H. W., AND R. L. KING. 1938. An Experimental Study on Mitosis in the Somatic Cells of Wheat. Biol. Bull. **75**: 189–207.

BERGNER, A. DOROTHY, A. G. AVERY, AND A. F. BLAKESLEE. 1940. Chromosomal Deficiencies in *Datura stramonium* Induced by Colchicine Treatment. Am. Jour. Bot. **27**: 676–683.

BLAKESLEE, A. F., AND A. G. AVERY. 1937. Methods of Inducing Doubling of Chromosomes in Plants by Treatment with Colchicine. Jour. Hered. **28**: 393–411.

BROWN, NELLIE A. 1939. Colchicine in the Prevention, Inhibition, and Death of Plant Tumors. Phytopathology **29**: 221–231.

CHAMBERLAIN, C. J. 1932. Methods in Plant Histology. University of Chicago Press, Chicago.

DERMEN, HAIG. 1940. Colchicine Polyploidy and Technique. Bot. Rev. **6**: 599–635.
——— AND NELLIE A. BROWN. 1940. Cytological Basis of Killing Plant Tumors by Colchicine. Jour. Hered. **31**: 197–199.
GRIGSBY, B. H. 1946. Some Effects of 2,4-D on Ragweed and Certain Woody Plants. Mich. Agri. Exp. Sta. Quart. Bull. **28**.
HAVAS, LASZLO J. 1937. Colchicine, "Phytocarcinomata" and Plant Hormones. Nature **140**: 191–192.
HAWKES, J. G. 1942. Some Effects of the Drug Colchicine on Cell Division. Jour. Genetics **44**: 11–22.
JAMES, W. O., AND F. B. HORA. 1940. The Effect of Cyanide on the Respiration of Barley. Annals of Botany **4**: 107–118.
JOHANSEN, D. A. 1940. Plant Microtechnique. McGraw-Hill, New York.
KODANI, M. 1941. The Structure of the Salivary Gland Chromosomes of *Drosophila melanogaster*. Jour. Hered. **32**: 147–156.
LANG, A. G. 1936. A Stable, High-Contrast Mordant for Hematoxylin Staining. Stain Tech. **11**: 149–151.
LEVAN, ALBERT. 1938. The Effect of Colchicine on Root Mitoses in *Allium*. Hereditas **24**: 471–486.
———. 1939. Cytological Phenomena Connected with the Root Swellings Caused by Growth Substances. Hereditas **25**: 87–96.
——— AND G. OSTERGREN. 1943. The Mechanism of C-mitotic Action — Observations on the Naphthalene Series. Hereditas **29**: 381–443.
LEVINE, MICHAEL, AND SIDNEY GELBER. 1943. The Metaphase Stage in Colchicinized Onion Root-tips. Bull. Torrey Bot. Club **70**: 175–181.
MILLER, E. C. 1938. Plant Physiology. McGraw-Hill, New York.
NEWCOMER, E. H. 1946. Concerning the Duality of the Mitochondria and the Validity of the Osmiophilic Platelets in Plants. Am. Jour. Bot. **33**: 684–695.
SEIFRIZ, WM. 1943. Protoplasmic Streaming. Bot. Rev. **9**: 49–123.
STEINITZ, LOTTI M. 1943. The Effect of Lack of Oxygen on Mitosis in Barley. Am. Jour. Bot. **30**: 622–625.
STERN, HERBERT. 1946. The Permeability of Cells Undergoing Nuclear Division. Trans. Royal Soc. of Canada **40**: 141–148.
SULLIVAN, B. J., AND H. I. WECHSLER. 1947. The Cytological Effects of Podophyllin. Science **105**: 433.
WALKER, RUTH I. 1938. The Effect of Colchicine on Somatic Cells of *Tradescantia paludosa*. Jour. Arnold Arbor. **19**: 158–162.
WENT, F. W. 1945. Auxin, the Plant-growth Hormone, II. Bot. Rev. **11**: 487–496.

EXPLANATION OF PLATES 10–14

PLATE 10: Controls—root tip tissues grown in Shive's nutrient solution

Figs. 1, 2. *Narcissus*; Zirkle fixation; meristem.
Fig. 3. *Narcissus*; Zirkle fixation; region of maturation.
Fig. 4. *Narcissus*; Zirkle fixation; region of elongation.
Fig. 5. *Allium*; weak Flemming fixation; showing mitosis.
Fig. 6. *Allium*; weak Flemming fixation; showing spindle fibers.

PLATE 11: Colchicine, 0.2% (0.005M) concentration; *Allium* root tips

Fig. 7. 13 hours; Zirkle fixation; meristem.
Fig. 8. 25 hours; Zirkle fixation; meristem.
Fig. 9. 61 hours; Zirkle fixation; meristem.
Fig. 10. 37 hours; Zirkle fixation; region of elongation.
Fig. 11. 13 hours; Zirkle fixation; region of elongation.
Fig. 12. 49 hours; Zirkle fixation; region of elongation.

PLATE 12: Colchicine (continued)

Fig. 13. 61 hours; Zirkle fixation; region of maturation.
Fig. 14. 13 hours; Zirkle fixation; region of maturation.
Fig. 15. 37 hours; Zirkle fixation; region of maturation.
Fig. 16. 25 hours; weak Flemming fixation; showing lobed nucleus and c-mitotic chromosomes.
Fig. 17. 13 hours; weak Flemming fixation; showing c-mitotic chromosomes.

PLATE 13: Indole-3-acetic acid, 0.001% concentration; 25 hours; *Narcissus* root tips

Fig. 18. Zirkle fixation; meristem.
Fig. 19. Zirkle fixation; region of maturation, periblem.
Figs. 20, 21. Zirkle fixation; region of elongation.
Fig. 22. Zirkle fixation; region of maturation.
Fig. 23. Zirkle fixation; region of elongation.
Figs. 24, 25. Chicago fixation; showing unusual amount of mitosis.

PLATE 14: Figs. 26–30, KCN; Figs. 31–33, 2,4-D; *Allium* root tips

KCN; 0.05M concentration; 25 hours:
Fig. 26. Zirkle fixation; meristem.
Figs. 27, 28. Weak Flemming fixation; note "ragged" chromosomes.
Fig. 29. Zirkle fixation; region of elongation.
Fig. 30. Weak Flemming fixation; note "ragged" chromosomes.
2,4-D:
Fig. 31. 0.05% concentration; 13 hours; Zirkle fixation; meristem.
Fig. 32. 0.05% concentration; 13 hours; weak Flemming fixation; chromosomes resembling c-mitotic ones.
Fig. 33. 0.1% concentration; 25 hours; Zirkle fixation; region of elongation.

PLATE 10

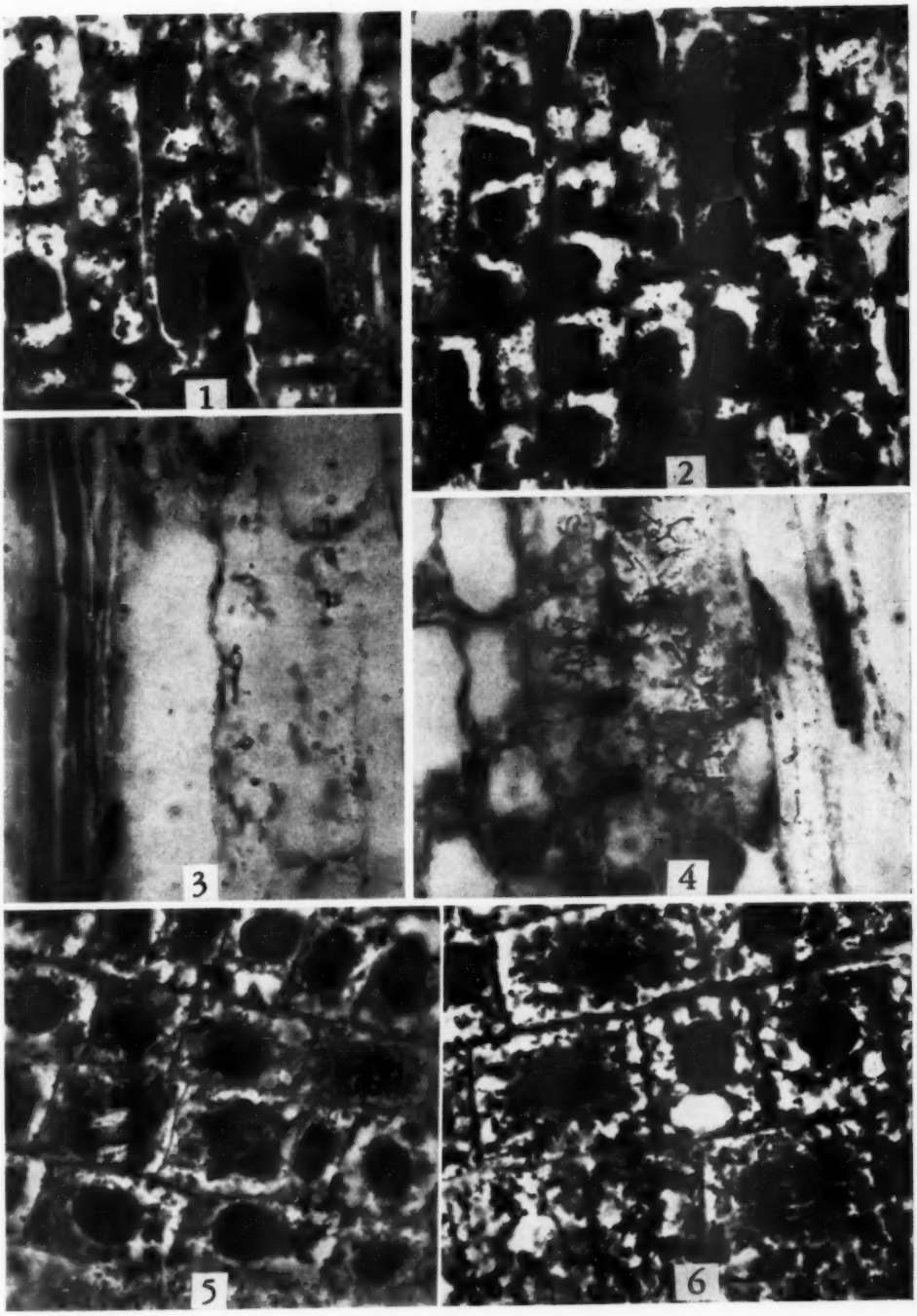


PLATE 11

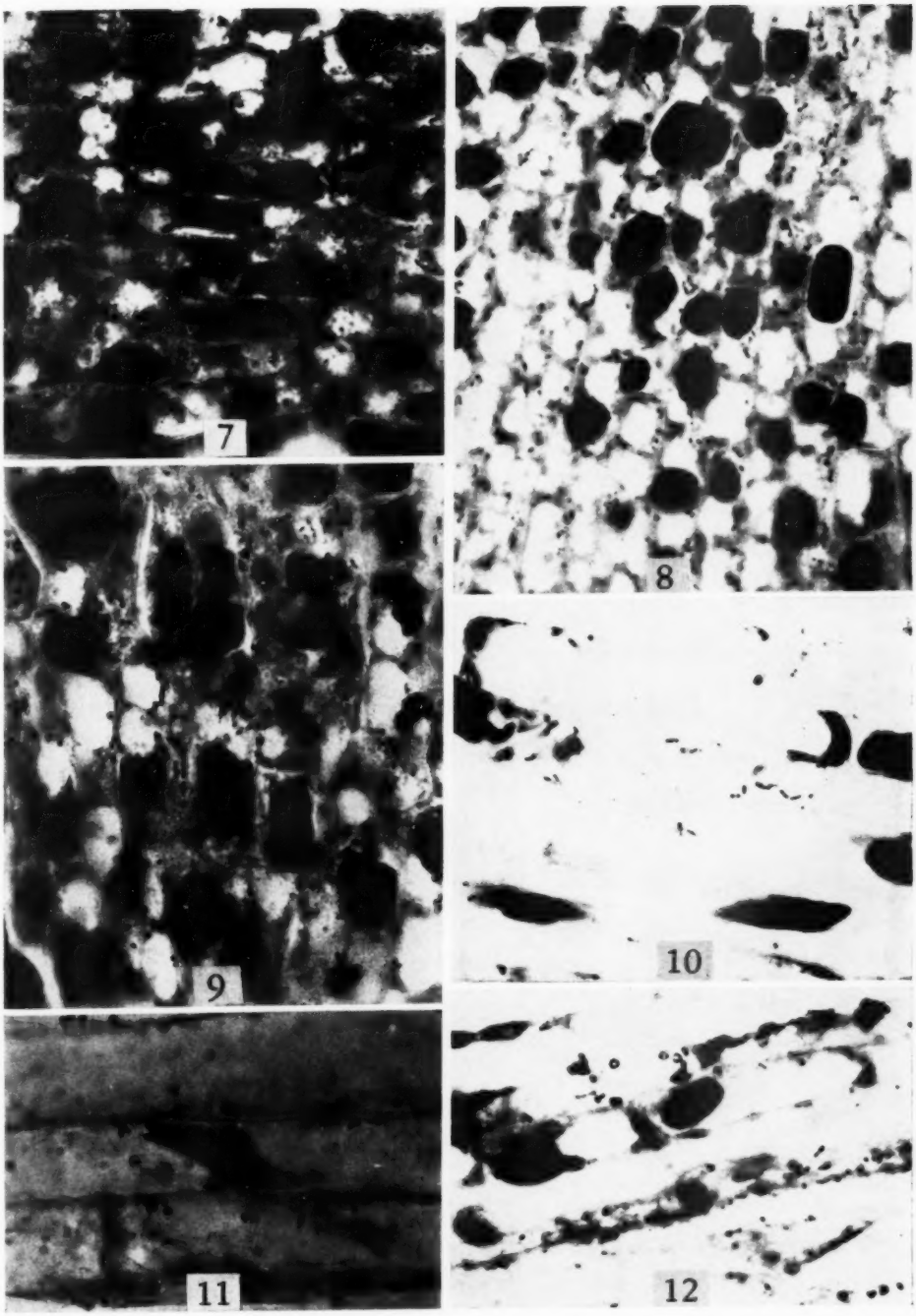
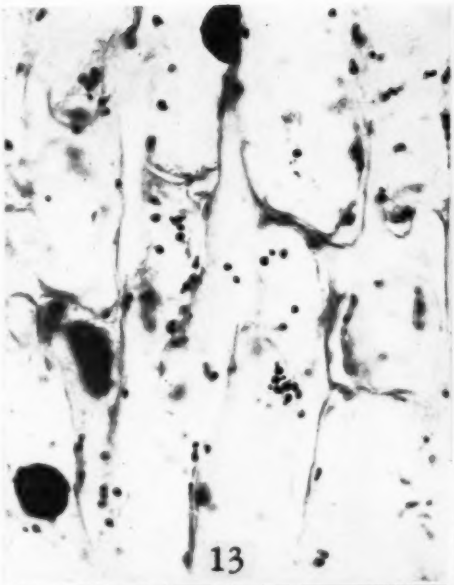


PLATE 12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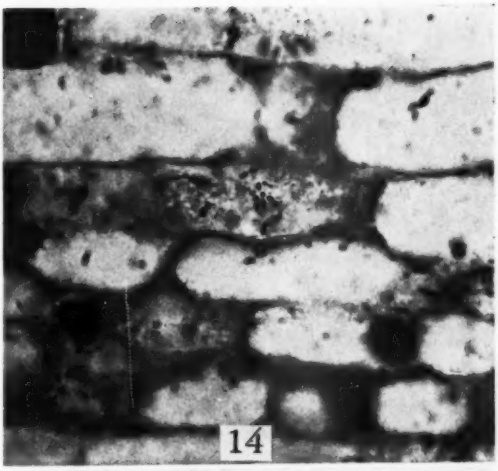
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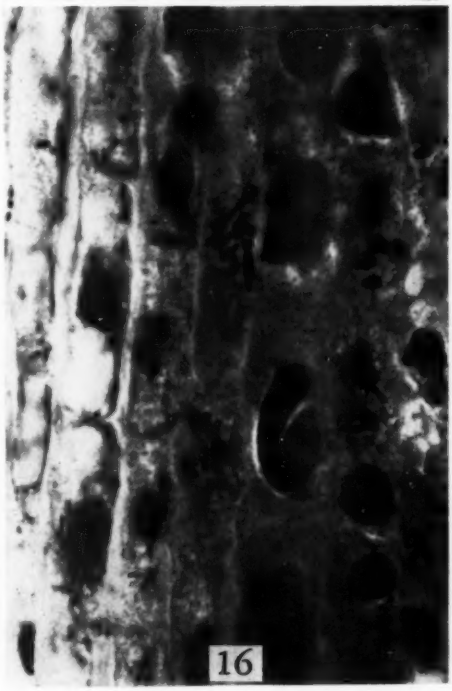
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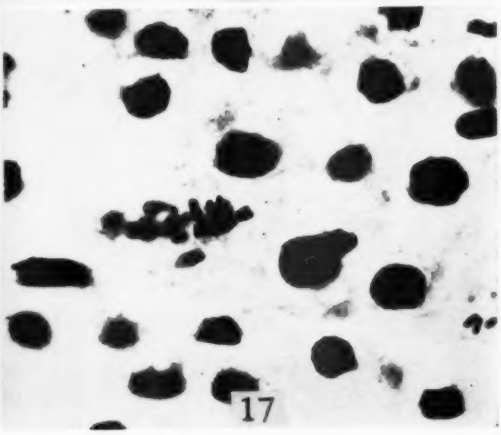
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PLATE 13

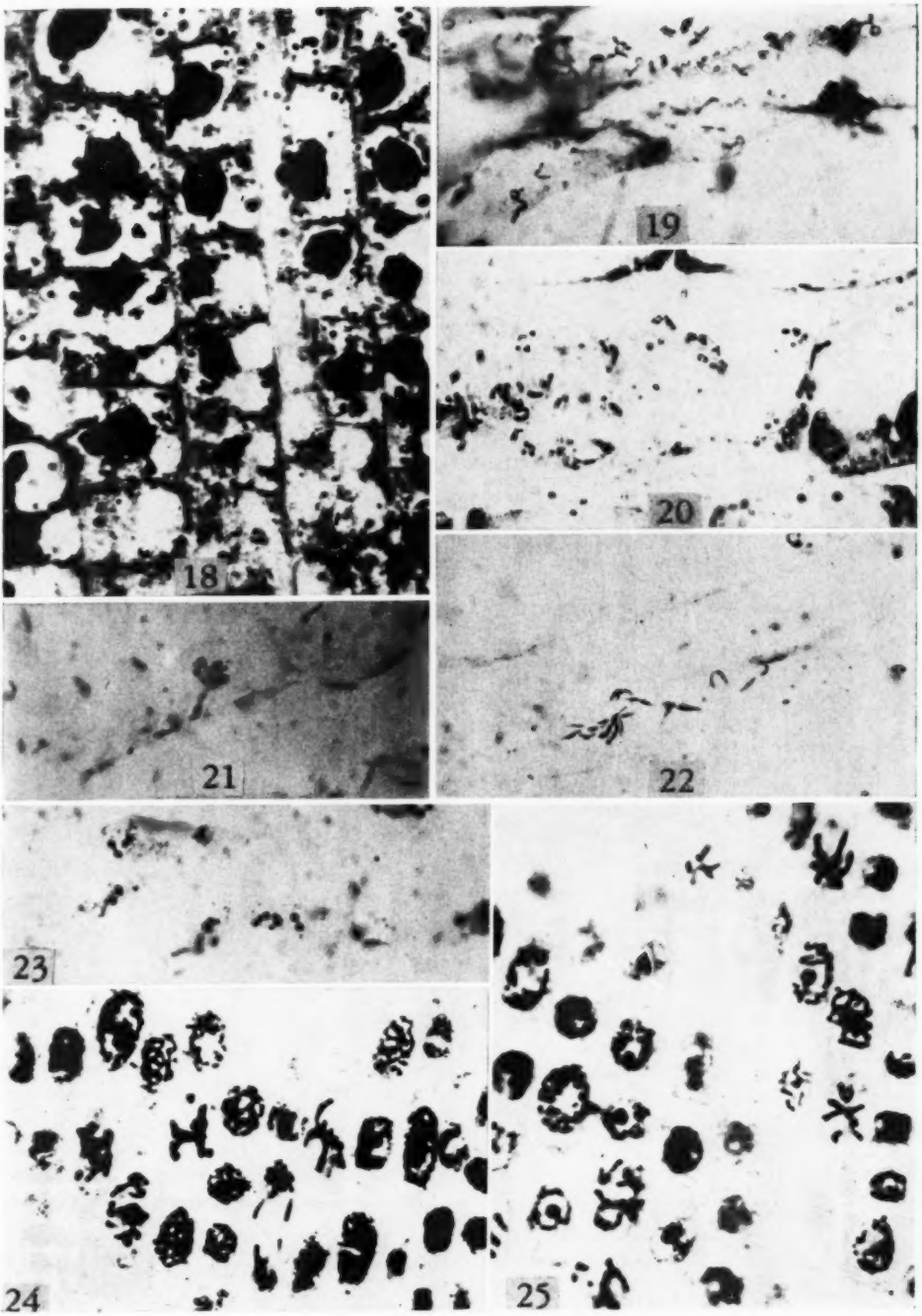
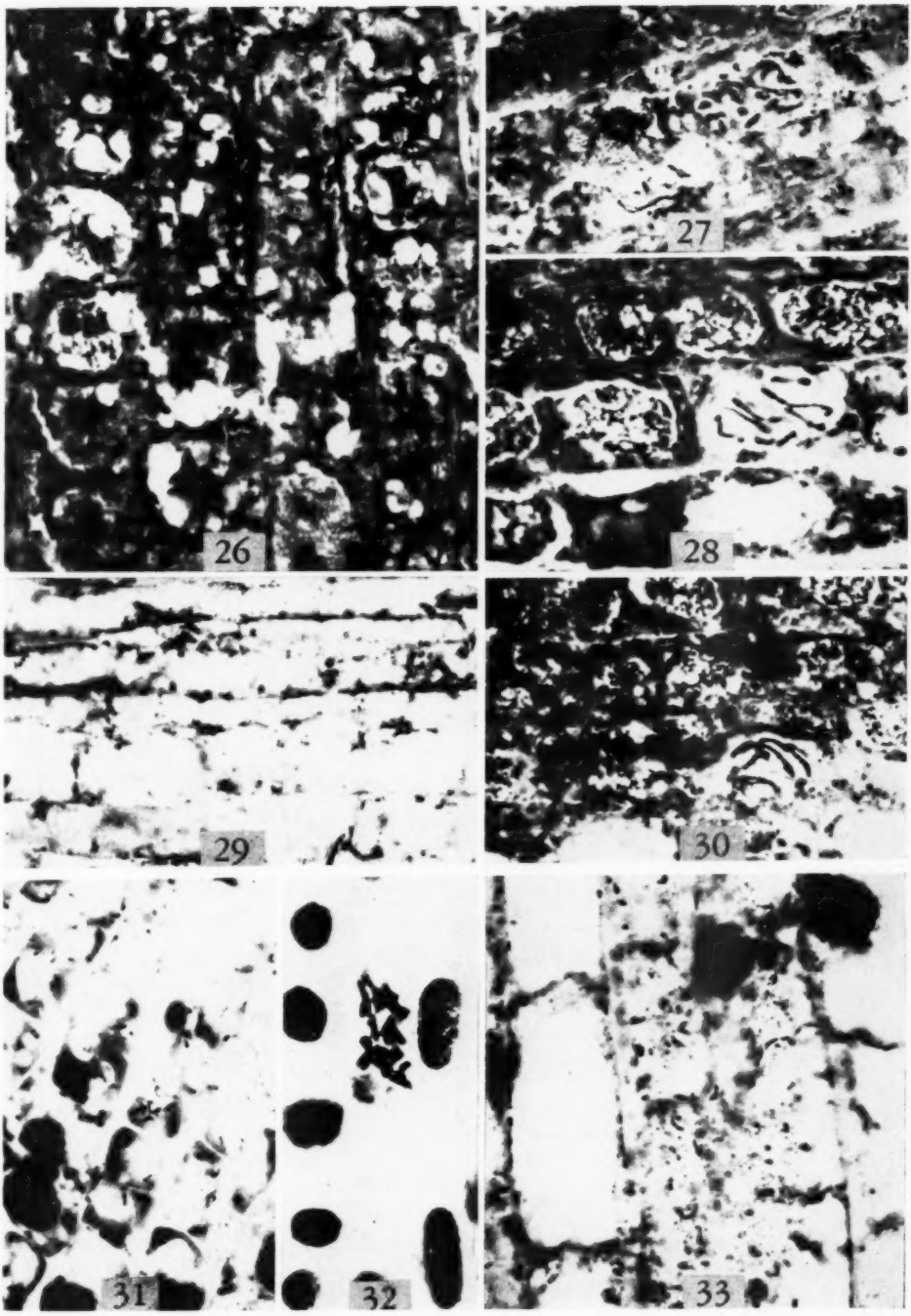


PLATE 14



A SECOND REPORT ON PARASITIC COPEPODS COLLECTED AT BEAUFORT, N. C.

By A. S. Pearse

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Eighteen Figures

Through the courtesy of Dr. Reinard Harkema the writer received seven parasitic copepod crustaceans collected from fishes during August, 1947. These are in addition to those already reported from the Beaufort Region (Pearse, 1947). Two of them are new. The findings are described in the following systematic account. Grateful acknowledgement is made to Paul L. Illg, who compared the writer's specimens with those in the United States National Museum and made constructive suggestions.

Order Copepoda

Suborder Caligoida

Family caligidae

Caligus mutabilis Wilson 1905

A single female was taken from the channel bass, *Sciaenops ocellatus* (L.), on August 20.

Family euryphoridae

Paralebion elongatus Wilson 1911

Three females were taken from a sharp-nosed shark, *Scoliodon terrae-novae* (Richardson), on August 20.

Family anthosomidae

Lernanthropus longipes Wilson 1932

Two females were found on the channel bass, *Sciaenops ocellatus* (L.), on August 20.

Family eudactylinidae

Kroyeria spatulata n. sp.

Four females, two of which carried egg strings, were taken from a sharp-nosed shark, *Scoliodon terra-novae* (Richardson), on August 20.

Carapace one-fourth wider than long, with lateral margins rounded but angulate and also rounded at the posterior lateral angles; styliform processes (Figs. 1, 6) reaching the anterior fourth of the fourth thoracic segment and bifid at the tip. Fourth thoracic segment a little longer than second and third,

which are about equal; fifth segment a little longer than any of the others and widened a little posteriorly. The fused fifth and genital segment is narrower than the thoracic segments, is a little more than three times as long as the head and thorax, and is nearly fifteen times as long as wide. Abdomen composed of a single segment, tapered posteriorly, one-seventh as long as fifth-genital segment. Caudal rami (Fig. 9) a little more than one-fourth the length of the abdomen; tipped with two plumose setae, a plain seta, two short spines, and two blunt tubercles.

First antenna (Fig. 2) 6-segmented, the first segment longest, the terminal segment tipped with four long and four short setae. Second antenna (Figs. 3, 4) short and stocky, the movable finger stout and moderately curved, the fixed finger broad, spatulate, rugose at tip. Second maxilla (Fig. 5) with basal segment short, second segment curved, and terminal claw about one-third as long as second segment. Maxilliped with basal segment straight and little swollen; terminal claw as long as basal segment but curved sharply just beyond the middle.

All the legs are biramose and the rami are 3-segmented. The terminal segment of the short endopod of the first leg (Fig. 7) is armed with a terminal, non-plumose seta and seven strong terminal and lateral spines. The segments of the first exopod bear 1, 1, and 3 plumose setae and the terminal segment has one non-plumose seta. The rami of the fourth leg (Fig. 8) are about equal in length. The endopod bears 1, 1, and 3 (short) plumose setae and 0, 3, and 5 medial spines; the exopod, 1, 1, and 5 plumose setae and a short terminal non-plumose seta and three small sub-terminal spines. The egg strings (Fig. 10) are linear; on one female each contains 27 eggs, on the other, 39. Length of type female, 6.0 mm.; of egg-bearing females, 7.5 mm.

Type: U. S. National Museum No. 84219.

Male, unknown.

This species is named for the unique spatulate character of the fixed arm of the chela of the second antenna. It somewhat resembles *Krøyeria papillipes* Wilson 1932, but differs from it in the character of the second antenna, the lack of papillae on the middle endopod segment of all legs, the armature of the legs and the caudal rami, and the length of the styliform process.

Nemesis atlantica Wilson 1922

Two females were collected from a sharp-nosed shark, *Scoliodon terrae-novae* (Richardson), on August 20.

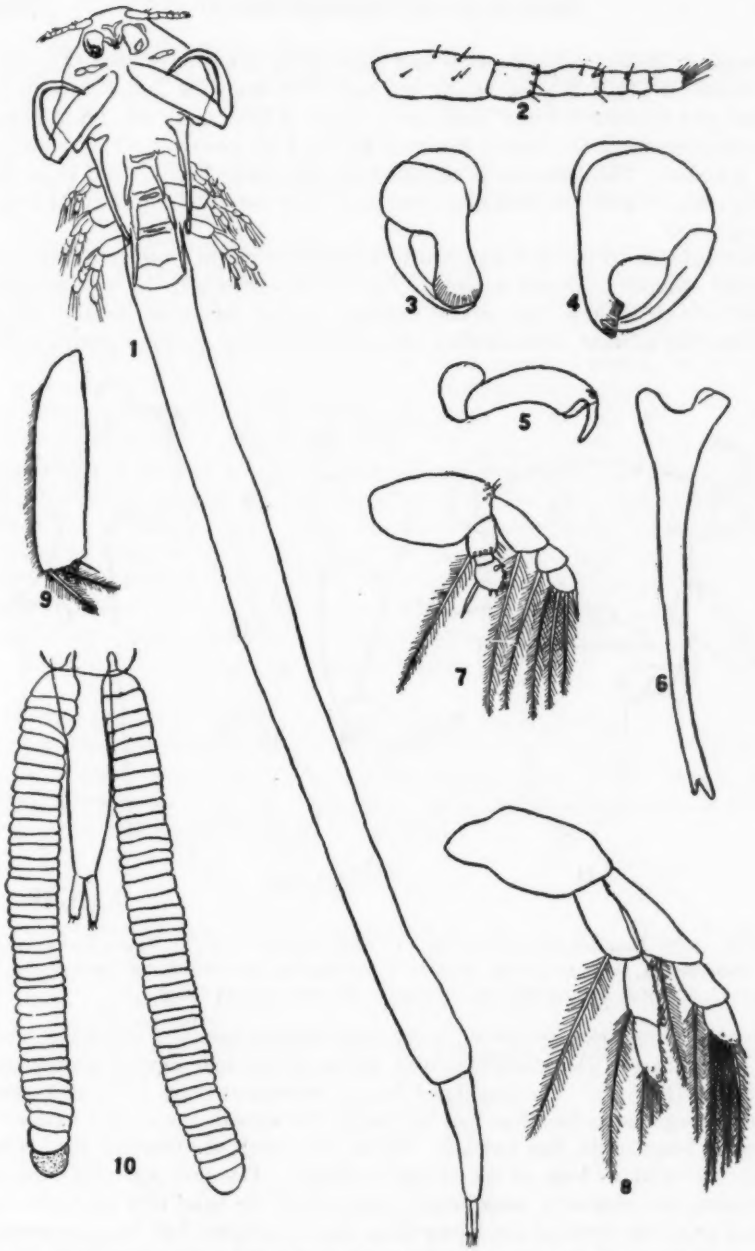
Eudactylinella alba Wilson 1932

Five females, one with eggs, were taken from a spotted whip ray, *Aetobatus narinari* (Euphrasen), on August 19.

Family DICHELESTHIIDAE

Hatschekia harkema n. sp.

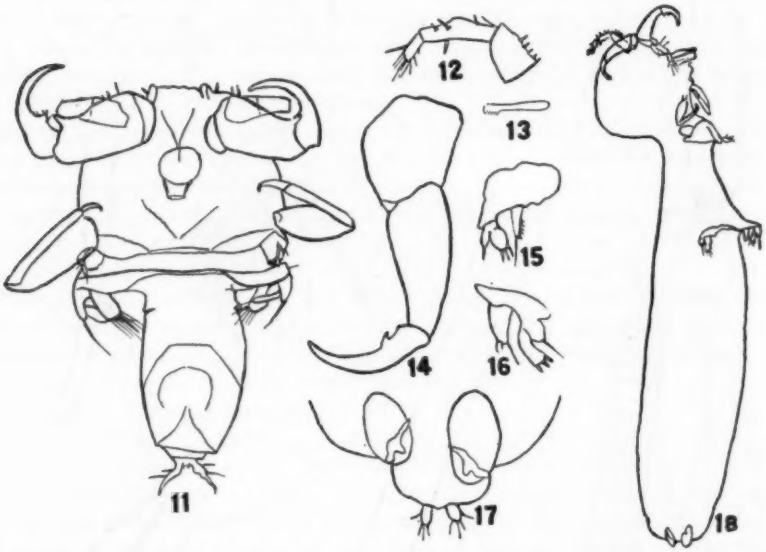
Five females and one male were collected from a spiny boxfish, *Chilomycterus schoepfi* (Walbaum), on August 13.



FIGS. 1–10. *Kroyeria spatulata* n. sp.: 1, female ventral view; 2, first antenna; 3, 4, second antennae; 5, maxilliped; 6, styliform process; 7, right first leg; 8, right fourth leg; 9, right caudal ramus; 10, abdomen and egg strings.

Female.—Head swollen dorsally and followed by a narrower neck (Fig. 18): the former is about 0.4 mm. wide, the latter 0.2 mm.; the linear body in its widest part is about 0.4 mm. wide; total length of head and body 1.8–2.4 mm. The anterior end of the body is more tapered than the posterior, which is gradually rounded. The abdomen is minute (0.04 mm. long; Fig. 17) and bears the caudal rami, which are 0.02 mm. long and each has three terminal and one lateral setae.

First antennae (Fig. 12) 3-segmented, the middle segment longest, the terminal segment shortest. Second antenna (Fig. 14) 3-segmented; the first segment about as wide as long; the second segment tapered somewhat distally, about twice as long as wide; terminal claw two-thirds as long as second segment, acute,



FIGS. 11–18. *Hatschekia harkema* n. sp.: 11, male, ventral view; 12, female first antenna; 13, mandible; 14, second antenna, female; 15, left first leg, female; 16, right second leg, female; 17, abdomen and caudal rami of female; 18, side view of female.

curved, bearing a recurved tooth on the inside near its base, and with a low tubercle at the base. The mandibles bear five teeth on their medial margin near their tips (Fig. 13). The maxilliped bears a prominent sharp tooth at its base; the first segment is less than half as long as the second; the second segment is equal in length with, but twice as wide as, the third; the terminal claw is less than one-third as long as the second segment. The first legs (Fig. 15) are biramous; the exopod is indistinctly 2-segmented, the basal lobe bears two terminal setae, the terminal lobe bears three spines; the inner lobe bears a terminal seta and five medial spines. The second leg (Fig. 16) is biramous; the exopod bears three terminal spines and a lateral seta; the endopod is tipped by three setae.

Male (Fig. 11).—Very minute, 0.4 mm. long. The head is covered by a dorsal plate which is rounded in front and truncate behind; this is slightly wider than long. The first two segments of the thorax are as wide as the head and clearly defined. The other thoracic segments and the genital segment are fused and are almost as long as the head and preceding thoracic segments. The abdomen is one-fifth as long as wide; it bears two long pointed appendages, each of which has two lateral setae.

The first antenna is short and truncate. The second antennae and maxillipeds are similar to those of the female but relatively larger and stronger. The first legs are biramose; the 2-segmented exopod bears a terminal seta, the endopod is rough at the tip. The second legs are also biramous and the exopod is 2-segmented; the exopod bears a lateral seta on the basal segment and a terminal seta on the slender distal segment; the endopod bears six terminal setae.

Types: U. S. National Museum No. 84217.

This species differs from Wilson's (1913) *H. oblonga* in the greater length of its thoracic segments, in having a strong spine at the base of the terminal claw of the second antenna, and the greater number of spines on the thoracic legs. In Wilson's (1922) key to the genus Hatschekia the species agrees with *H. linearis* in having 3-segmented antennae and yet disagrees in that the second thoracic segment is narrower than the head; the width of the head agrees with *H. hypoglossi* but does not agree in that the antennae are not 5-segmented. None of the females carried egg strings, so they may have been immature. The species is named for the collector, Dr. Reinard Harkema.

Four copepods that were previously reported (Pearse, 1947) were also collected by Dr. Harkema from the same hosts: *Ergasilus lizae* Krøyer and *Naobranchia lizae* (Krøyer) from *Mugil cephalus* L.; *Pseudocycnus buccatus* Wilson from *Scomberomorus maculatus* (Mitchill); and *Pseudochondracanthus diceraus* Wilson from *Sphaeroides maculatus* (Bloch & Schneider).

REFERENCES

PEARSE, A. S.
1947. Parasitic copepods from Beaufort, North Carolina. Jour. Elisha Mitch. Sci. Soc. **63**: 1–16.

WILSON, C. B.
1913. Crustacean parasites of West Indian fishes and land crabs. Proc. U. S. Nat. Mus. **44**: 189–277.
1922. North American parasitic copepods belonging to the family Dichelesthiidae. Proc. U. S. Nat. Mus. **60**: 1–100.

A NEW MEMBER OF THE PLASMODIOPHORACEAE

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Plate 15

A new species of *Octomyxa* parasitic in *Brevilegnia linearis* was found in a soil collection made by the writer from the City Park, Florence, S. C., in June 1947. The swollen ends of the *Brevilegnia* hyphae suggested that it might be *Octomyxa Achlyae* Couch, Leitner, and Whiffen (1939) and upon close examination the resting spores were seen to be in groups of eight. A study was begun to determine whether the spherical galls were due to *O. Achlyae* or to a new species.

Material was killed and fixed in Randolph's modified Navashin fluid (Johansen, 1940), embedded in paraffin, and sectioned at 10 microns. As a stain, Couch's (1932) modification of Gram's gentian violet technique was used. With this technique, the "protomitotic" type of nuclear division within the developing parasite plasmodium was demonstrated (Plate 15, fig. 3). This primitive type of nuclear division was also reported by Couch et al.

Using the Löffler flagella staining technique (Couch, 1941), zoospores were seen to have one short anterior flagellum and one long posterior flagellum. Biflagellate heterokont zoospores were found also in *O. Achlyae.* Ledingham (1934) reported biflagellate zoospores in *Plasmodiophora brassicae* and *Spongospora subterranea,* and zoospores with one long and one short flagellum in *Polymyxa graminis* (1939).

Thus various characteristics considered as prerequisites of a member of the Plasmodiophoraceae by different workers, mainly hypertrophy of the host, "protomitotic" type of nuclear division, negative cellulose reaction, resting spores in a definite grouping, and biflagellate heterokont zoospores, are all fulfilled by this fungus.

At the suggestion of Dr. J. N. Couch, a comparison was made of the size of galls, zoosporangia, and resting spores of *O. Achlyae* with those of the fungus parasitic on *Brevilegnia,* and a distinct difference was found. The galls of *O. Achlyae* measured 50–150μ, as compared to 30–90μ for those of the new species; zoosporangia of the former 6–16μ in thickness with 6–14 zoospores in each, zoospores of the latter 5.2–7.6μ with 4–6 zoospores in each; however the individual resting spores in *O. Achlyae* were smaller in diameter (2.4–3.2μ) than those of the parasite on *Brevilegnia* (2.8–4.9μ).

The host range studies also indicated a difference. Numerous attempts were made to induce parasitism of this fungus on *Achlya glomerata,* upon which *O. Achlyae* was found to be obligate, but all were negative. Negative results were also obtained with the following water molds: *Sapralegnia ferax, S. delica, S. diclina, S. litoralis, S. megasperma, Aplanes treleaseanus, Dictyuchus missouri-*

ensis, Isoachlya intermedia, I. itoana, I. unispora, Aphanomyces laevis, Protoachlya hypogyna, Achlya racemosa, A. americana, A. apiculata, A. colorata, A. caroliniana, A. crenulata, A. flagellata, A. recurva, A. proliferoides, Allomyces javanicus, A. moniliformis, Apodachlya pyrifera. However, *Geolegnia inflata* became parasitized when put into a dish with the parasite.

Octomyxa Brevilegniae n. sp.

Obligate parasite in *Brevilegnia linearis* Coker and *Geolegnia inflata* Coker and Harvey, causing spherical galls mostly on the ends of the hyphae of the host. Mature galls 30–90μ thick. Plasmodia of the parasite at maturity completely filling the galls and segmenting into zoosporangia; plasmodia developed later segmenting into resting spores in clusters of eight. Zoosporangia globose to ovoid, 5.2–7.6μ mostly 7μ, in diameter, thin-walled. Spores discharged through papillae which are formed only on some of the sporangia next to the host wall, the other peripheral sporangia and those deeper within the sorus discharging their spores through those furnished with papillae; zoospores biflagellate with one long posterior and one short anterior flagellum, 4–6 in a zoosporangium. Resting spores 2.8–4.9μ, mostly 3.5μ, in diameter, with smooth, somewhat thickened walls; germination unknown.

Walls of the zoosporangia and resting spores show a negative cellulose reaction with chlor-iodide of zinc.

The Latin diagnosis follows.

Fungus parasiticus in hyphis *Brevilegniae linearis* et *Geolegniae inflatae*. Maturis tumoribus 30–90μ in diametro. Plasmodiis plantae parasiticae maturitate tumores omnino complentibus. Primis plasmodiis formantibus zoosporangia; plasmodiis postea factis formantibus sporas perdurantes in massis octonas cuique massae. Zoosporangiis globosis vel ovoideis, parietibus tenuibus, 5.2–7.6μ in diametro, plerumque 7μ; zoosporis biflagellatis cum uno longo flagello posteriore et uno brevi anteriore; 4–6 in zoosporangio. Sporis perdurantibus 2.8–4.9μ in diametro, plerumque 3.5μ, cum parietibus levibus leviter incrassatis; germinatione incomperta.

SUMMARY

A new species of *Octomyxa* parasitic in *Brevilegnia linearis* and *Geolegnia inflata* is described.

Nuclear divisions of the developing plasmodium are of the so-called "protomitotic" type.

Zoospores are biflagellate with one long and one short flagellum.

The host range is limited, so far as known, to the above two species of water molds.

The writer is sincerely grateful to Dr. J. N. Couch for his encouragement and guidance and to A. W. Ziegler for water mold cultures.

LITERATURE CITED

COKER, W. C. 1927 Other Water Molds from the Soil. Jour. Elisha Mitchell Sci. Soc. **42**: 207–226.

COUCH, J. N. 1932 The Development of the Sexual Organs in *Leptolegnia caudata*. Amer. Jour. Bot. **19**: 584–599.

———, LEITNER, JEAN, AND WHIFFEN, ALMA. 1939 A New Genus of the Plasmodiophoraceae. Jour. Elisha Mitchell Sci. Soc. **55**: 399–408.

——— 1941 The Structure and Action of the Cilia in Some Aquatic Phycomycetes. Amer. Jour. Bot. **28**: 704–713.

HARVEY, J. A. 1925 A Study of the water molds and Pythiums occurring in the Soils of Chapel Hill. Jour. Elisha Mitchell Sci. Soc. **41**: 151–164.

JOHANSEN, D. A. 1940 Plant Microtechnique. McGraw-Hill Book Co., New York.

LEDINGHAM, G. A. 1934 Zoospore Ciliation in the Plasmodiophorales. Nature **133**: 534.

——— 1939 Studies on *Polymyxa graminis* n. gen. n. sp., a Plasmodiophoraceous Root Parasite of Wheat. Canadian Jour. Res. **17**: 38–51.

EXPLANATION OF PLATE 15

Fig. 1. Habit Sketch of *Octomyxa Brevilegniae* on *Brevilegnia linearis*. Parasite causing hypertrophy of the tips of the host hyphae. ×120.

Fig. 2. Immature plasmodium causing hypertrophy of hyphal tip. Host hypha five days old, plasmodium two days old. ×750.

Fig. 3. Plasmodium stained with Couch's modification of Gram's gentian violet technique. Vegetative nuclear divisions of the "protomitotic" type clearly visible in upper part of plasmodium. ×1080.

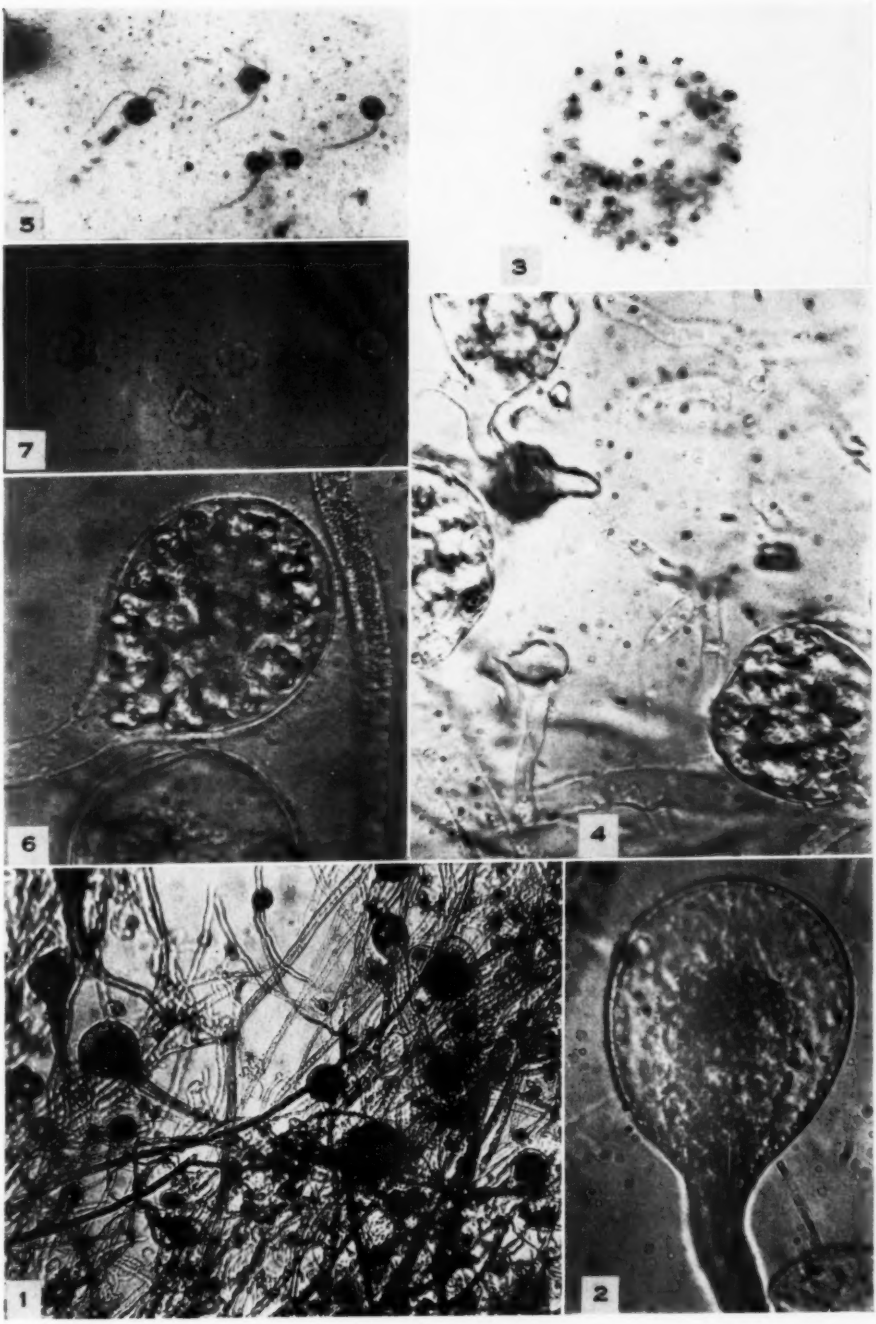
Fig. 4. Parts of three zoosporangial galls. Zoospores already formed within the zoosporangia in the gall at lower right. ×750.

Fig. 5. Biflagellate heterokont zoospores stained with the Löffler flagella-staining technique ×1080.

Fig. 6. Host hypha filled with the octo- groups of resting spores. ×750.

Fig. 7. Groups of eight resting spores of the parasite free of the host hypha. ×750.

PLATE 15



NOTES ON SOME HIGHER FUNGI

By W. C. Coker

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Plates 16–25

Hygrophorus Peckianus Howe. Bull. Torr. Bot. Club **5:** 43. 1874.
Camarophyllus Peckianus (Howe) Murrill. N. Amer. Fl. **9:** 389. 1916.

Plates 16 (inset) and 25, fig. 1

Cap 1–1.3 cm. broad, convex, not striate, dull, surface like leather or felt, not viscid, hygrophanous, light grayish buff when dry, deep smoky brown (blackish in places) when wet. Flesh 1 mm. thick, color of cap, very brittle, taste mild, odor keen and strong, remarkable and unlike that of any other mushroom, more like bad breath than anything else.

Gills thick, fleshy, color of unsoaked cap, distant, about 2 mm. broad, strongly decurrent by a broad tooth (arcuate).

Stem 2.5–3 cm. long, 1.6 mm. thick above, tapering downward, blackish below, color of gills above, smooth, granular at very top, stuffed, becoming hollow, pliable.

Spores (of No. 2620) subglobose to short-ellipsoid with a small excentric mucro, smooth, 3.7–4 x 4–5.5μ.

This is a peculiar and rare plant, not previously reported south of New York and Michigan. It is easily recognized by its color, small size, and remarkable odor. The spores are not rough as described by Howe, Peck, and Murrill, the granular contents having a misleading effect. When the contents are plasmolyzed by salt solution the wall is seen to be perfectly smooth, as described by Smith and Hesler (Lloydia **5:** 12, 1942). *Hygrophorus Peckii*, which we also have in Chapel Hill, has a strong but very different musky odor and is strongly glutinous, etc. *Hygrophorus Peckianus* should be carefully compared with the English plant *H. foetans* Phillips (Grevillea **7:** 74, pl. 121, fig. B, 1878).

North Carolina. Chapel Hill. No. 2620. In rocky soil by path, mixed woods, July 9, 1917. No. 2798. In mossy grass in a lawn, July 28, 1917. No. 5334. In damp soil in deciduous woods, July 10, 1922. Spores ovoid, 3.6–4.2 x 4.8–6.5 μ.

Hygrophorus amygdalinus Peck. Bull. Torr. Bot. Club **25:** 322. 1898.

Plates 16 and 25, fig. 2

Cap up to 3 cm. wide, when young nearly hemispheric, more or less gibbous with margin strongly inturned, at maturity plane in center with broadly drooping margin, surface gray-drab at all ages, viscid, fibrous, margin felted-spongy like the stem, representing an ephemeral veil which is an extension of the stem covering. Flesh pure white, firm, about 5–6 mm. thick near stem, rapidly thinning toward the margin; odor strong of bitter almonds; taste mild.

Gills pure white, about 2.5 mm. wide, rounded distally, pointed and either squarely adnate or more commonly slightly decurrent, rather distant and thick, about every other one short.

Stem up to 5 cm. long and 5 mm. thick in center, concolorous and with same surface as the margin of the young cap, minutely scurfy-squamulose, crooked, terete or somewhat grooved or flattened, stuffed with fibers which may separate, forming irregular hollows; base prevailingly pointed and yellowish but not always pointed and sometimes whitish.

Spores smooth, subellipsoid, proximal end somewhat narrowed, 5–6.2 x 10–13μ with one large droplet except when quite fresh. Basidia clavate, 7.5–9.5μ thick, projecting up to 11μ, not counting the sterigmata which may be 11μ long, 4-spored (a few apparently only 2-spored). No true cystidia but some pointed sterile threads present.

Murrill (N.A.F. **9:** 394) listed this species as a synonym of *H. hypothejus*, but we find it easily distinct in the characteristic odor, felted rather than glutinous cap margin and stem, pure white gills and larger spores. Dr. A. H. Smith has kindly confirmed our identification of this species.

We find no record of its occurrence except at the type station in the District of Columbia. Smith and Hesler have not found the species but have seen the types and make the following note (Lloydia **2:** 58, 1939): "Sections of the type show that it is a *Limacium* and that its spores measure 9–12 x 5–6.5μ. It needs further study."

North Carolina. Chapel Hill. No. 10698. In poor sandy soil on a low bank in pine woods, Nov. 14, 1937. No. 10700. Same spot as above, Nov. 21, 1937.

Hygrophorus rubropunctus Peck. Bull. N. Y. St. Mus. **116:** 49. 1907.
H. glutinosus Peck. Bull. N. Y. St. Mus. **54:** 950. 1902.

Plates 17 (bottom), 18, and 25, fig. 3

Cap up to 10 cm. broad, usually 5–7 cm., nearly pure white when quite fresh, becoming more or less buffy yellow, covered with thick gluten, as on lower part of stem.

Gills subdistant, adnate, decurrent by a line, nearly white, interveined in larger plants.

Stem short, stout, equal or tapering slightly upward, white, solid, not viscid above but lightly punctate there with concolorous dots which turn reddish on drying, glutinous below and strongly *scabrous-ridged*, base blunt.

Spores (of No. 13210) pure white, large, oval or subellipsoid, smooth, 5.6–7 x 9.3–12μ. Basidia (of No. 3771) about 10.5μ thick, 4-spored.

Gregarious in small colonies. In unexpanded buttons the thick gluten can be seen to be creamy yellow.

Easily distinguished from *H. Laurae* by stout, blunt stem which is much roughened downward, by the red dots on upper stem when dry, and by the larger spores. We find no previous illustration.

North Carolina. Chapel Hill. No. 919. In thick woods under oak, Oct. 15, 1913. No. 932. Dry woods, Battle Park, Oct. 16, 1913. No. 3771. Deciduous woods by Battle branch and in barren clay spot in pines, Nov. 18, 1919. Spores oval, 5.2–

7.4 x 9–11.2 μ. No. 4933. In woods, Dec. 7, 1921. Spores 5–6.7 x 7.4–11 μ. No. 13210. Ten plants; deciduous woods, Oct. 25, 1942.

Hygrophorus borealis Peck. Rept. N. Y. St. Mus. **26:** 64, 1874; Bull. **116:** 55. 1907.

Plates 17 (top) and 25, fig. 4

Gregarious and sparingly cespitose; cap (1) 2.5–3.7 cm. wide, strongly convex with drooping margin to irregularly plane, even or slightly depressed in center, hygrophanous, nearly pure white, watery white when moist, center at times faintly buff; margin even or substriate, neither cap nor stem at all viscid. Flesh a mere membrane except near center, white, not brittle, elastic; odor none, taste mild.

Gills distant, none forked, many short, interveined, arcuate-decurrent, about 4 mm. wide, thin, margin even.

Stem slender, crooked, irregular, usually collapsed here and there or down one side, about 5–7 cm. long and 6–8 mm. thick, subequal, base blunt and rounded or more or less pointed, surface quite smooth, fibrous, silky-shining, easily splitting, quite hollow or loosely fibrous-stuffed.

Spores (of No. 13209) pure white, oval-subpipshaped, with a prominent mucro, smooth, 5.2–6.5 x 7.4–10μ. On standing in the herbarium the spores become a pretty clear yellow, about Pinard yellow (Ridg.). See Smith and Hesler (cited below) for variations in size and number of spores on a basidium.

This seems to agree perfectly with *H. borealis* Peck (*Camarophyllus borealis* in Murrill), and we have recently had our determination confirmed by Dr A. H. Smith. Murrill reports it from no farther south than New Jersey but it has since been reported from Tennessee by Hesler (Journ. Tenn. Acad. Sci. **20:** 235, 1945) and from North Carolina by Smith and Hesler (Lloydia **5:** 19, 1942). We have examined a plant from Fort Lee, New Jersey, in the New York Botanical Garden Herbarium (Earle, Sept. 15, 1902) as *H. borealis*, and find the spores exactly as in our No. 13209 and also as in Hesler's collection from Tennessee.

We cannot find that the species has previously been illustrated.

North Carolina. Chapel Hill. No. 13209. In deciduous woods about 7 miles west of town, Oct. 25, 1942. Also Nos. 1974, 3756, 3762, 3778, 3870, 3890 from Chapel Hill.
Tennessee. Cades Cove. Hesler, No. 16574. Spores 5–6(6.8) x 7–9.3 μ.
New Jersey. Fort Lee. Ellis, coll. (N. Y. B. G. Herb.).

H. borealis forma **salmoneus** n.f.

Plate 25, fig. 5

Cap flushed with pinkish orange (light salmon) on one side and stem dull pink below, the pink spreading when plants are handled. Spores 4.3–5.5 x 7–10μ.

No. 3756 (entered above) was faintly pinkish on a part of the margin and stem turned faintly pink when rubbed.

North Carolina. Chapel Hill. No. 3745. Mixed woods, Nov. 13, 1919.

Craterellus calyculus (B. & C.) Burt. Ann. Mo. Bot. Gard. **1:** 338. 1914.

Stereum calyculus B. & C. Hooker's Journ. Bot. and Kew Misc. **1:** 238, 1849; Grevillea **1:** 161. 1873.

Thelephora subundulata Peck. Bull. Torr. Bot. Club **22:** 492. 1895.

Craterellus subundulatus Peck. Bull. N. Y. St. Mus. **67:** 27. 1903.

Craterellus albomarginatus Coker. Journ. Elisha Mitch. Sci. Soc. **43:** 139. 1927.

Plates 19 (bottom, right) and 25, fig. 6

In the Mitchell Journal above cited we published under the name *Craterellus albomarginatus* a little plant from Linville Falls, North Carolina. Later, in looking through the genus *Craterellus* at the New York Botanical Garden, we found a collection by Peck and Earle of *C. subundulatus* and recognized it as the same species. It was not included in Burt's monograph but was later recognized in his supplement (Ann. Mo. Bot. Gard. **13:** 312. 1926). We have also studied an ample collection of Chapel Hill plants and have come to the conclusion that they all belong to the species *C. calyculus*. The plants vary considerably in width of cap and irregularity of margin, and the hymenium dries more yellowish in some cases.

The species was originally described from South Carolina, and has been reported from North Carolina and (as *C. subundulatus*) from Delaware and New York, and Tennessee. In the Coweeta Experiment Forest in Macon County, N. C., we found a specimen that had assumed a petaloid shape from a nearly marginal stem, due apparently to its growth from the side of a bank.

We give below a slightly revised description.

Cap 4–15 mm. wide, deeply depressed to infundibuliform, cream buff to a darker buffy or grayish brown, dull, dry, inherently fibrous and radially roughened, usually with hispid squamules on marginal half, which is often bent downward and strongly crumpled. Flesh delicate, pliable, with a faint taste and odor like that of *C. cibarius*.

Hymenium pale buff to cinereous buff, tender, slightly rugulose, uneven, decurrent.

Stem about 1–2 cm. long and 1–1.5 mm. thick, smooth, glabrous, firm, pliable, concolorous with cap and with a small hollow; base not noticeably tomentose.

Spores (of No. 7464) internally granular when fresh, smooth, ellipsoid, 4.8–6 x 6.5–8.5μ; basidia long-clavate, most 4-spored but often 6-spored, 6–7.4μ thick and up to 35μ long.

In drying the cap color tends to become more cinereous and the hymenium ochraceous, and stems that collapse before drying are black. The entire plant is strongly hygroscopic, and after drying will regain its full size and shape in less than a minute. This character of reviving is a key character used by Murrill (N. Amer. Fl. **9:** 163) in separating *Plicatura* and *Xerotinus* from other genera of the tribe. He does not include this species, which was since recognized by Burt as a *Craterellus*.

Our plants are much smaller than *C. sinuosus* as shown by Fries (Icones **2:** pl. 196, fig. 2) and both cap and hymenium are more yellow; also the spore meas-

urements are distinctly smaller than those of *C. sinuosus* as given by Burt (6–7 x 10–12μ).

North Carolina. Chapel Hill. No. 7464. On damp clay soil, July 31, 1924.
Linville Falls. No. 8206. Type of *C. albomarginatus*. On bare earth just above the water of a spring, hemlock-rhododendron woods, Sept. 10, 1927.
Macon County. No. 12154. On bank by trail in Coweeta Experimental Forest, Aug. 12, 1939.

Psalliota pocillator Murrill. Mycologia **33:** 446. 1941.

Plates 20, 21, and 25, figs. 8–10

Cap up to 8.5 cm. broad, subovate, soon broadly conical and gibbous, expanding to plane with a gibbous center, the margin involute; color when young brown all over or the margin paler and center darker, soon dark sepia on the broad umbo, rather abruptly fading to light buffy brown (about pale avellaneous of Ridg.); surface glabrous and smooth, subshining. Flesh nearly white, delicate, not brittle, very thin, about one mm. thick nearly to center where it abruptly thickens to 5 mm., a mere membrane at the margin, turning slowly dull red when bruised (not when cleanly cut); odor peculiar, like stale meat or fish, taste unpleasant, causing flow of saliva and leaving a sticky feel in the mouth.

Gills free, close, narrow, about 5 mm., delicate, margin even, whitish, soon pale pink then darker to about color of cap center.

Stem long and slender, nearly equal, more or less crooked, 3–7 mm. thick and up to 13 cm. long, very smooth and shining above and below the veil, inserted for a short distance into the humus and soil and ending abruptly in a compressed bulb which is concave above and surrounded with a thick, blunt, raised margin like the saucer for a flower pot; stem white at first then more or less pale avellaneous except in the soil where it remains white; bulb connected with one or several slender white strands; stem flesh firm and rigid and very solid except for a small, ill-defined, loosely fibrous central column. Veil ample and permanent, pale then brown, attached at about 8–10 mm. from the top, thin but set below with spongy flecks and often divided into more or less complete layers.

Spores (of No. 13587) dark sepia (no trace of purple), oval, 2.8–3.5 x 4–5.5μ. Basidia clavate, 4-spored, about 6.7 x 22μ; cystidia none.

This is a peculiar plant. In form and stature it is much like *P. abruptibulba* but differs strikingly from it in the abruptly dark umbo, the entirely glabrous stem, in change to reddish, not yellow, when bruised, the unpleasant taste, and the very small spores, and from that and all other species in the cup-shaped bulb. At no age is there any connection between the rim of the bulb and cap or stem, the very young button sitting in the bulb like a ball in a cup. The odd shape of the bulb is more obvious where the plant is growing in light leafy humus. When in earth it is obscured by the attached soil. The colors of the cap are well retained in drying, the abruptly dark brown center contrasting strongly with the much lighter color of the surrounding surface. In the first collection there were 40-odd plants in cespitose groups or single over an area of several square yards.

This striking plant was described from Gainesville, Fla., and so far as we know has not previously been reported from anywhere else. It is strange that so conspicuous and prolific a species should have been so rarely found. Murrill says

"excellent for the table," but our well known mycophagist, Prof. N. B. Adams of Chapel Hill, finds it inferior to others of the genus.

North Carolina. Chapel Hill. No. 13587. In humus under shrubs in the Arboretum, July 21, 1944. No. 13593. Same place in Arboretum, Aug. 11, 1944. No. 13602. Same place as above, Sept. 25, 1944. About 30 plants, all stages, in a compact group, some fused at base. No. 13608. In scattered clusters from same colony as above, Sept. 29, 1944. These plants were water-soaked from rains and showed considerable rose tint in the cap.

Hydnellum diabolus Banker. Mycologia **5:** 194. 1913.

Hydnellum carbunculus (Secr.) Banker. Mem. Torr. Bot. Club **12:** 151. 1906. Not *Hydnum carbunculus* Secr. Myc. Suis. **2:** 151. 1833.

Cap 5–11.5 (15) cm. broad, convex, uneven, surface of growing parts soft, taking the imprint of a finger, white, turning red-brown when rubbed or exposed, then through darker brown to almost black with some whitish or pale fawn areas left here and there, especially on the margin; fresh, damp, growing parts secreting small droplets of clear bright red juice which disappear, leaving dark red-brown stains. Flesh of cap thick, soft throughout or somewhat harder downward and strongly zoned with dark and light brown layers when fresh, far less conspicuously so when dry; taste quite acrid, odor marked but not strong, medicinal or of old hickory nuts, not unpleasant.

Spines very short, 3 mm. long or less, crowded, light fawn color with white tips, then dark brown, not decurrent.

Stem short, 2–4 cm. long, 1–1.5 cm. thick, tough, flesh dark brown to blackish, with no distinct spongy layer but outer flesh softer.

Spores (of No. 14081) light fawn color, between avellaneous and vinaceous buff (Ridg.), subglobose to oblong in general outline, distinctly and rather irregularly warted, 3.7–4.2 x 4.2–5.4μ.

Our plants, which are usually found in pine straw, grow around the needles and imbed them within the fungus body. The plants shrink very little in drying. A bit of the flesh put in water turns it reddish.

Illustrations: Coker. Journ. E. M. Sci. Soc. **34:** pls. 14, 15, 28. 1919.

North Carolina. Chapel Hill. Nos. 1341, 1869, 1951, 1968 (as published in Journ. Mitch. Soc. cited above). No. 3811. Pine woods, Dec. 2, 1919. No. 14056. In pine straw, east bank of University Lake, Oct. 16, 1946.

Chatham County. No. 14081. Growing up through dense pine straw under *Pinus taeda* in sandy old field, Mann's Chapel, Nov. 4, 1946. No. 14299 and No. 14301. In pine grove, near same place as above, Oct. 18, 1947. No. 14311. In second growth pine grove by road to Mt. Carmel, Oct. 19, 1947.

Durham County. No. 14326. Under pines near New Hope Creek, Oct. 23, 1947.

Hydnellum suaveolens (Scop.) Karst. Medd. Soc. Fauna et Fl. Fenn. **5:** 27. 1879.

Hydnum suaveolens Scop. Fl. Carn. **2:** 472. 1772.

Hydnum compactum Pers. Comm. Schaeff., p. 57. 1800.

Hydnum boreale Banker in White. Bull. Torr. Bot. Club **29:** 553. 1902.

Sarcodon gravis Coker. Journ. Elisha Mitch. Sci. Soc. **55:** 376. 1939.

Plate 19 (top, and bottom, left)

Plants single or in colonies, at times confluent; cap (3.6) 6–12 (14) cm. wide, circular, the thick sterile margin more or less uneven; surface convex then plane, more or less scrobiculate, at times strongly so, pure white all over at first and remaining so toward the margin until old, very soft-felted; taking the imprint of a finger, the felt collapsing in center and gradually outward to a soft, smooth, tan-brown surface which may be faintly tinted with violet, fawn, or olive. Flesh soft above, gradually harder downward, conspicuously zoned with soaked drab and white layers, the drab becoming blue or greenish, especially downward, on exposure. Taste none; odor variable in intensity, faint when first collected but after a few hours usually distinctly aromatic, as of wintergreen or peppermint, lost for the most part in drying.

Stem short, about 1–2 cm. long and up to 1.5 cm. thick, surface firm, without a superficial mass of tomentum, deep indigo blue or blackish or blue-black; mycelium blue, at least at times; flesh solid, strongly and closely zoned with deep blue, even when freshly cut.

Spines crowded, up to 6 mm. long, pale drab, then drab-brown with pale tips, often descending far down the stem, at times even to the substratum.

Spores (of No. 13324, good print) fawn-colored, irregularly angled and bluntly warted, 3–3.7 (4.2) x 3.8–5μ. Basidia clavate, 4-spored, about 4.8–5.2μ thick.

Sarcodon gravis, as described by me from Highlands, N. C. (see above), is this species. Since that time we have found a number of plants in several consecutive years, evidently from the same colony. They are all essentially alike. Our plants show less vivid blue than some of the European and northern examples, but the blue color is quite evident and all other characters are the same.

This species seems not to have been found heretofore in the east except for Canada and Maine. For a western form, see entry under Wyoming.

Illustrations: Coker. Journ. E. M. Sci. Soc. **55**: pl. 35 (top) and pl. 44, fig. 4 (as *S. gravis*). 1939.

North Carolina. Highlands. No. 10563. By road around Ravenel Lake, Aug. 19, 1937 (type of *Sarcodon gravis* Coker). No. 11740. Beside stream near entrance to Rhododendron Trail from road by Ravenel Lake, July 20, 1940. No. 12822. Same spot as above, under hemlock and rhododendron, July 12, 1942. No. 12834, same spot (remainder of large colony), July 15, 1942. No. 12874. Same spot as above, July 27, 1942. No. 13317. Same place as above, July 24, 1943. No. 13324. Same place as above, July 26, 1943. No. 13487. Under rhododendron and hemlock, just across road from entrance to Rhododendron Trail, Aug. 17, 1943.

Maine. Mt. Desert Island. Dr. Fred J. Seaver, coll. (N. Y. B. G. Herb. and U. N. C. Herb.)

Wyoming. Albany County. No. 14699. On duff in coniferous forest, altitude 9500 feet, Medicine Bow Mts., Sept. 6, 1940. Ragnhild and W. G. Solheim, coll. (Univ. of Wyo. and U. N. C. Herb.) Spores irregularly angled and warted, 4–5.2 x 4.2–6.5 μ. These plants differ in larger spores, and stouter, heavier form of the plant itself. It may be the same form as reported and illustrated by Kauffman from Tolland, Colorado (Pap. Mich. Acad. Sci. **1**: 116, pl. 33, 1921).

Canada. Quebec. Under balsam, St. Aubert, July 15, 1940. H. A. C. Jackson, coll. (No. 1832 in Snell Herb.)

Sistotrema confluens Pers. Disp. Meth. Fung., p. 28, 1797; Syn. Meth. Fung., p. 551. 1801.

Hydnum sublamellosum Bull. Herb. Fr., pl. 453, fig. 1. 1789.

Plate 22 (top)

We first published notes on this species with illustrations in the Journal of the Elisha Mitchell Scientific Society **41:** 285, pls. 63, 65, figs. 8–11, 1926, having found it twice in Chapel Hill on pine needles. Since then we have found it abundantly in several colonies in fine condition. Our photograph shows a thick mat of needles (*P. echinata*) with the fungus growing up among them. The perfectly fresh unweathered plants are at first finely tomentose with slender hairs, soon practically glabrous and slightly viscid.

Some European illustrations, particularly Bulliard's and Greville's, show a plant in size and appearance hardly like our delicate form, but others, as W. G. Smith's fig. 87, are more like ours. Patouillard's figure (Hymen. Eur., pl. 3, fig. 19) shows the 6-spored basidia. Konrad and Maublanc (Icon. Sel. Fung. **5:** pl. 426, fig. 1) show the species with bright red stalks and place it, as does Patouillard, in the Polyporaceae.

We have specimens in our herbarium as follows: North Carolina (Chapel Hill), Tennessee, Virginia, New Hampshire, and Ontario. It has also been reported from North Carolina by Schweinitz, Alabama (Earle, Banker), New York (Peck), and Vermont (Burt). Our photograph was made from the collection listed below.

North Carolina. Chapel Hill. No. 13241. Second growth pine grove, Nov. 7, 1942. Seven or eight colonies were seen, most of them forming segments of rings; one perfect ring about 3½ ft. in diameter. The appearance at a little distance was as if crumbled chalk had been dropped in the pine needles.

Hydnodon thelephorum (Lév.) Banker. Mycologia **5:** 297. 1913.

Plates 22 (bottom) and 25, fig. 11

Since our first report of this peculiar tropical plant in Chapel Hill (Journ. E. M. Sci. Soc. **41:** 279, pls. 56 and 64, figs. 16, 17. 1926), we have found other fine examples of it, always near the bases of deciduous trees on banks by branches. Our plate shows a part of two of these collections. In a later collection (No. 13835) one of the fused clusters reached a size of 5 x 6.5 cm. Good prints show the spores to be coral pink (Ridgway). A few thin-walled cells with swollen bases were found among the basidia (fig. 11). Basidia, spores, etc., as described before.

North Carolina. Chapel Hill. No. 13809 and 13810, Aug. 17, 1945. No. 13835, Aug. 24, 1945 (W. C. C., coll.).

Boletus Ananas M. A. Curtis. Amer. Jour. Sci., ser. 2, **6:** 351. 1848.

Plate 23 (top)

Cap strongly convex or center flat, up to 7.5 cm. broad (not counting veil), covered all over with a thick shaggy thatch which is a fine terra cotta pink below, the thick outer fibers paler, almost white, this thatch expanding at the margin

as a tough veil membrane which is pink below, the paler fibers extending as torn flaps for as much as one to two centimeters. Flesh of cap up to 1.5 cm. thick, firm, durable, not grubby, white, instantly blue when cut, soon white again, then dull pinkish leather color on standing; taste mildly acid, odor none.

Tubes mustard yellow, turning to deep reddish brown, then dark blackish brown, blackish on bruises, dark green-blue when cut, then brown; up to 1.5 cm. deep, mouths even, about 1 mm. wide, strongly depressed at stem.

Stem, with bulb, up to 11 cm. long, subequal, 12–14 mm. thick in center, smooth, white, the very tip with a sharp bright pink ring about 5–7 mm. wide, then brownish when exposed.

Spores (of No. 13756) in light print brown with faint purplish tint, in heavy print blackish brown, strongly striate, ellipsoid, 6–7 x 13.5–15.5μ.

Bulb about 2–2.5 cm. thick, extending as plates or fibers apparently connected to rotten wood. In No. 13756 one plant was from the base of an oak and one among roots of pine.

Illustrations: Coker and Beers. Boletaceae of North Carolina, pl. 64, fig. 11.

South Carolina. Myrtle Beach. No. 13756. July 13, 1945. No. 13779. Attached to bark at base of a pine tree, July 26, 1946. Spores dark brown, ellipsoid, strongly striate, 6.3–7.5 x 13.6–17.3 μ.

Boletus sphaerosporus Peck. Bull. Torr. Bot. Club **12:** 33. 1885.

Plates 23 (bottom) and 25, fig. 12

Five large heavy plants about 8–13 cm. broad, plano-convex, margin strongly inturned and distinctly free, for as much as 5 mm. in places; surface quite glabrous, shining, with a viscid removable cuticle, not acid to the tongue, color reddish brown, near russet (Ridg.), becoming much darker, blackish brown when rubbed. Flesh thick, up to 3.5 cm. at stem, thinning rapidly near margin and extending as a thick free membrane, white, then quickly brown when exposed, tender but firm; taste slight, not pleasant, somewhat flat and alkaline, odor negligible.

Tubes up to one cm. long, easily removable, large, very variable in size, 2–3 mm. in diameter toward margin, mouths much elongated radially near stem where they may be 8 mm., inset with smaller, more shallow ones, depressed at stem and descending for several mm. as reticulations or scarely depressed in places.

Stem stout, more or less plug-like, rounded below into a blunt base, length up to 6.5 cm. and thickness 3.4 cm. near top, glabrous, color dull pale yellow above, concolorous with cap below. Flesh light brown, then darker brown when cut.

Veil very thick and conspicuous, remaining attached about the middle of the stem as a heavy roll collapsed upward, pallid whitish when fresh, becoming discolored to dark brown.

Spores pale yellow-brown under microscope, subglobose, smooth, 6–7.4 x 7–9μ, with a distinct oil globule.

This peculiar and very interesting plant was described by Peck from one dried plant from Wisconsin (Bull. T. B. C. **12:** 33. 1885). He discusses its peculiarities at some length and is particularly concerned with the prominent veil. In our plants this is obviously a veil and not a volva. This heavy veil and the unique subglobose spores led him to suggest that it might be a sufficient distinc-

tion to consider it a new genus. Murrill (N. Amer. Flora **9:** 155) reports it from Wisconsin, Iowa and Minnesota.

Illustrations: Peck. Bull. Torr. Bot. Club **12:** pl. 49, figs. 1, 2. 1885.
Minnesota. St. Paul. T. Kommedahl. (Received by us from him by air mail Oct. 9, 1945. No. 13994.)

Boletus placidus Bon. Bot. Zeit. **19:** 204–205. 1861.
B. albus Pk. Rept. N. Y. St. Cab. **23:** 130. 1873.

Plate 24

Since the appearance of our book on the Boletaceae we have collected good material of this species at Highlands, N. C., and are giving below a more adequate description, with photographs. Three of these collections grew from the same mycelium in a damp place (rhododendrons, hemlocks, etc.) by a brook north of the laboratory. The photograph shows a peculiarity noted in all the plants from this spot. The pore surface, while perfectly functional, shows odd pits and cavities of different sizes and depths. These are almost certainly not caused by insects as the plants showed no signs of insects and the appearance is different from that of insect attacks on other boletes. Also it is hardly to be expected that if caused by insects this peculiarity would appear on all of the individual collections from this spot, made at different times.

Cap up to 9.5 cm. wide, convex then gibbous, glutinous, *pure white* when young, then lightly tinted with lemon yellow toward margin, quite smooth, no flecks or fibers, margin very narrowly free. Flesh thick in center, nearly white then lemon tinted toward tubes and margin; no taste or odor.

Tubes short, up to 5 mm., adnate, small, angular, walls very thin; color pale creamy yellow, then dull straw yellow; when young with droplets of nearly clear viscid fluid which turn light pink then browish; tube surface always uneven, deeply and irregularly pitted, in some cases with pits so deep as to expose the cap flesh.

Stem 6–8.5 cm. long, 8–13 mm. thick, solid, nearly equal, more or less crooked, dotted all over with pale, then brownish pink droplets; base of stem nearly always bent and pointed, inserted into pure white, ropy mycelium.

Spores (of No. 13275) pinkish clay color in a good print, ellipsoid, smooth, 3–3.7 x 5.6–7.5μ

This species is easily distinguished from all the other white or whitish boletes by the very dark, reddish brown color of the dried plants and by the spores.

North Carolina. Highlands. No. 8970. Under white pines, July 29, 1931. No. 11739. In woods, mostly white pines, by Ravenel Lake, July 20, 1940. No. 12707. Under white pines, Aug. 26, 1941. No. 13275. A fine colony extending over 6 or more feet, single or two or three together, by a branch north of the laboratory, July 13, 1943. No. 13289. Same place as above, July 19, 1943. Spores 3–3.6 x 6.8–8(9), longer than in the earlier collection from the same place. No. 13579. Same spot as above, Sept. 6, 1943. Only one plant; cap nearly pure white but creamy in places. Spores 3–3.6 x 6–8 μ.

Cyphella cupulaeformis B. and Rav. Grevillea **2:** 5. 1873.

Plate 25, figs. 14, 15

A very large collection, crowded by scores in places, was made from the bark of six living cedar trees in the Negro cemetery, Chapel Hill, N. C., Nov. 3, 1946 (No. 14087). Notes on this species have been published once before by us (Mitchell Journal **36:** 150, pl. 30, fig. 3, 1921).

Cups attached by their sides and hanging vertically. Spores (good spore print on a slide) shaped like "Jack rocks," a few showing only two or three papillae but most with four in outline, making the spore "squarish" or slightly rectangular, 4–5 x 5–6μ, not counting the projections, otherwise up to 6.5 x 7.4–8μ. Threads of flesh 3.4–4μ thick, with many clamp connections, anastomoses and some branching.

The species seems to have been reported only a very few times since it was collected by Ravenel in South Carolina and Georgia. Among the localities recorded are the Great Smoky Mountains National Park (Mycologia **33:** 574, 1941) and Bermuda (Mycologia **38:** 186, 1946).

Rhizopogon truncatus Linder. Rhodora **26:** 196, pl. 148, fig. 3, 5–7. 1924.

Plate 25, figs. 16, 17

In August 1937 we found a very beautiful little *Rhizopogon* on an exposed roadside bank at Highlands, N. C. (No. 10511). There were two plants, about 1 cm. thick, bright sulphur yellow all over at first, then clear wax yellow when dry; peridium very thin; gleba light ashy color, with cavities so small as to be scarcely visible to the eye; odorless and tasteless. Spores ellipsoid, 3.5–4 x 7–8.3μ, with a conspicuous cup. Basidia about 5μ thick and 13.5μ long.

In all essential characters this agrees with *R. truncatus*, which has been known before only from the type locality in New Hampshire. See Coker and Couch, Gasteromycetes, p. 36, pl. 26 (top) and pl. 106, fig. 13, 1928.

EXPLANATION OF PLATE 25

Fig. 1. Hygrophorus Peckianus. No. 2620. Spores.
Fig. 2. H. amygdalinus. No. 10700. Spores.
Fig. 3. H. rubropunctus. No. 13210. Spores.
Fig. 4. H. borealis. No. 13209. Spores.
Fig. 5. H. borealis forma salmoneus n.f. No. 3745. Spores.
Fig. 6. Craterellus calyculus. No. 7464. Spores.
Fig. 7. C. calyculus. No. 7464. Basidia, showing variation in number of sterigmata.
Fig. 8. Psalliota pocillator. No. 13602. Outline of one young plant, part of another, and (center) a very young button in its cup.
Fig. 9. P. pocillator. No. 13587. (Above) Base of stem with cup; (below) section through two fused bases, the inner margin of cup also fused.

Fig. 10. P. pocillator. No. 13587. Spores.
Fig. 11. Hydnodon thelephorum. No. 13809. Hymenial cell with swollen base.
Fig. 12. Boletus sphaerosporus. No. 13994. Spores.
Fig. 13. Cyphella cupulaeformis. No. 14087. Spores.
Figs. 14, 15. C. cupulaeformis. No. 14087. Showing bit of hypha with clamp connection and a basidium with two sterile cells.
Figs. 16, 17. Rhizopogon truncatus. No. 10511. Basidium and spores.

Figures by Alma Holland Beers except figs. 8 and 9, which are by Alleda Burlage. All spore drawings ×1620; figs. 7, 11, 14, 15, 16 ×810; figs. 8, 9 ×$\frac{3}{4}$.

PLATE 16

Hygrophorus amygdalinus. No. 10700.
Hygrophorus Peckianus (inset). No. 2620. Nat. size.

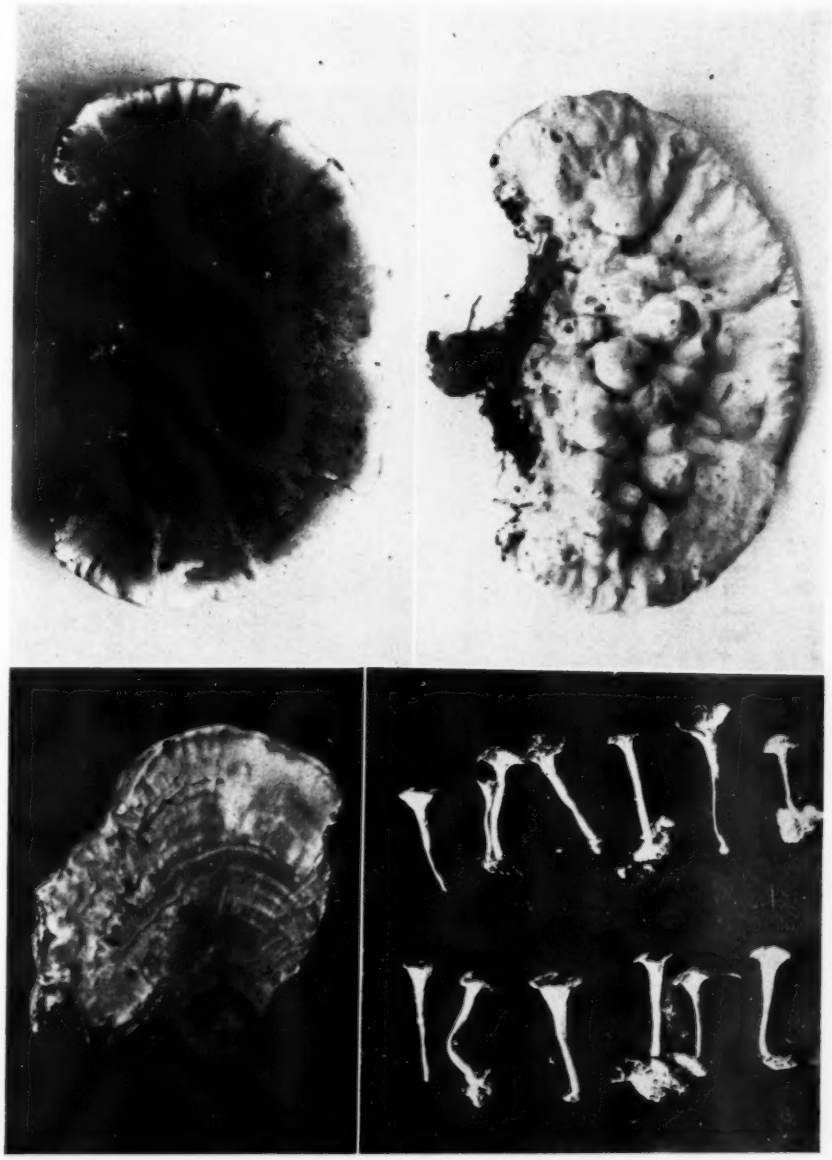
PLATE 17

Hygrophorus borealis (top). No. 13209.
Hygrophorus rubropunctus (bottom). No. 13210.

PLATE 18

Hygrophorus rubropunctus? No. 3771.

PLATE 19

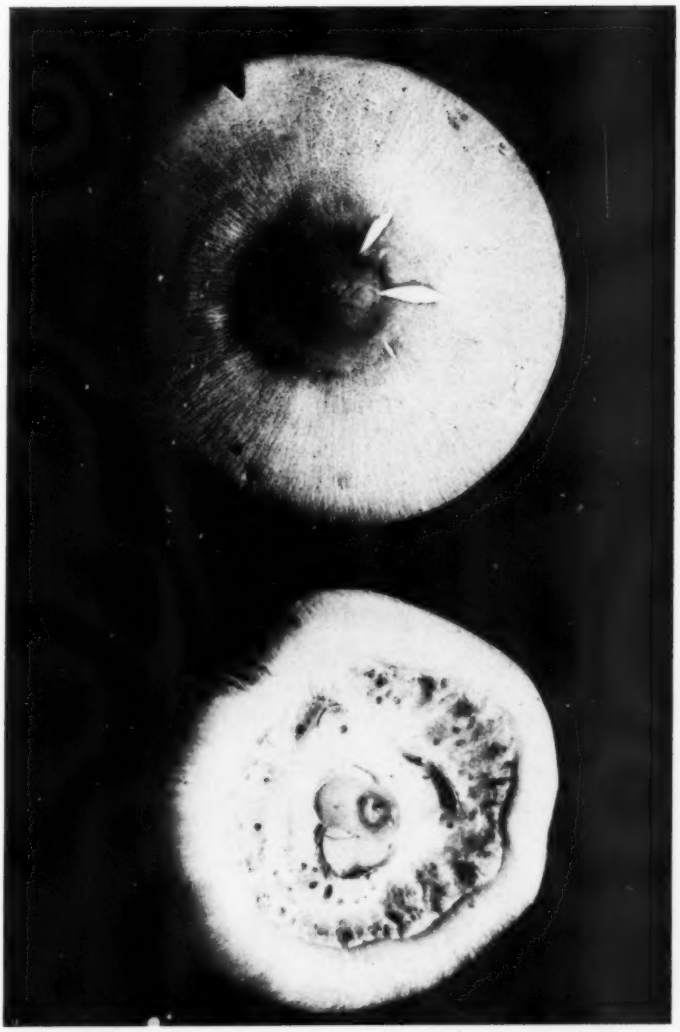


Hydnellum suaveolens. No. 13317 (top), × ⅔; No. 11740 (bottom, left), nat. size.
Craterellus calyculus (bottom, right). No. 7464.

PLATE 20

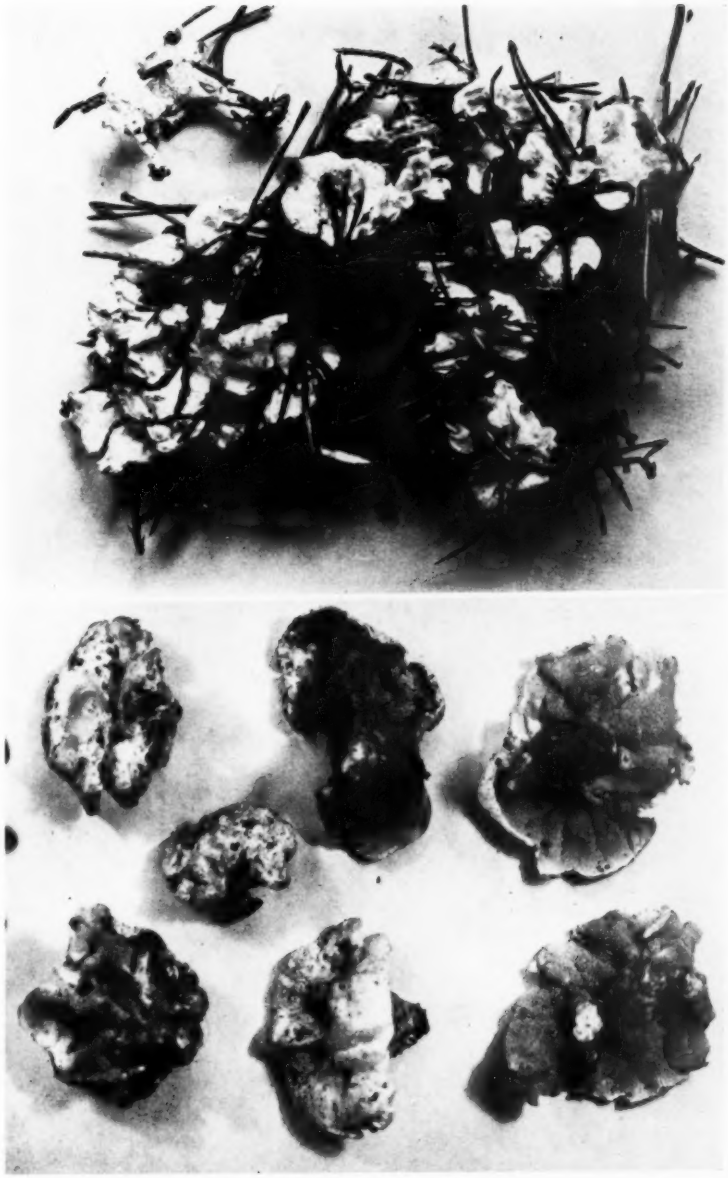
Psalliota pocillator. No. 13587. Photograph by J. N. Couch.

PLATE 21



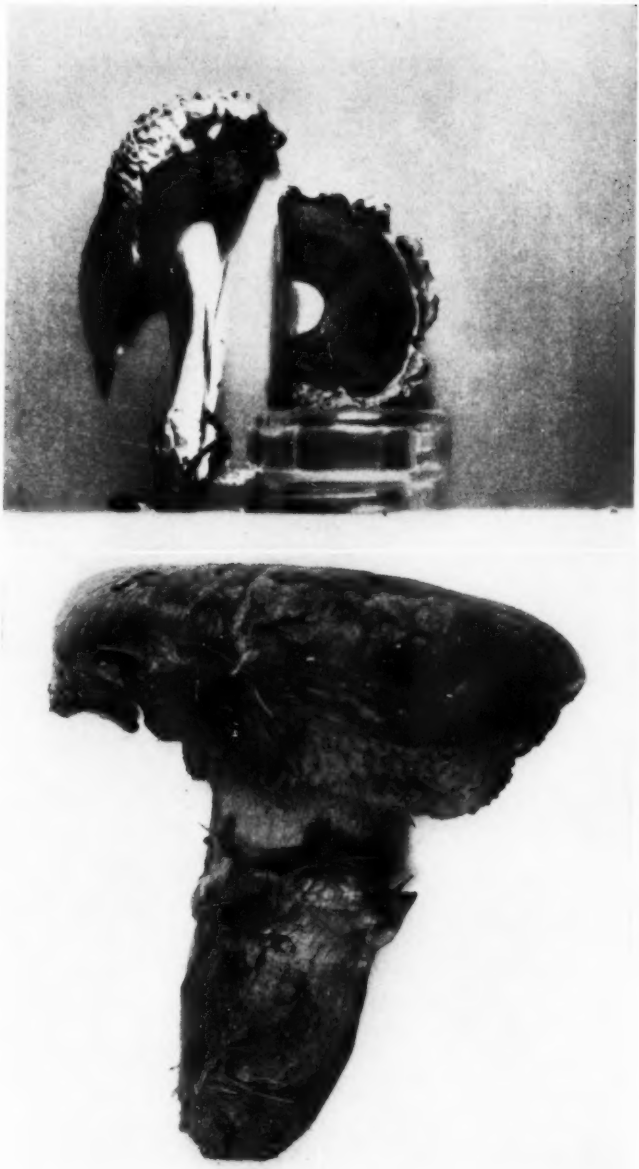
Psalliota pocillator. No. 13587. Photograph by J. N. Couch.

PLATE 22



Sistotrema confluens (top). No. 13241.
Hydnodon thelephorum (bottom). Nos. 13809 and 13810.

PLATE 23



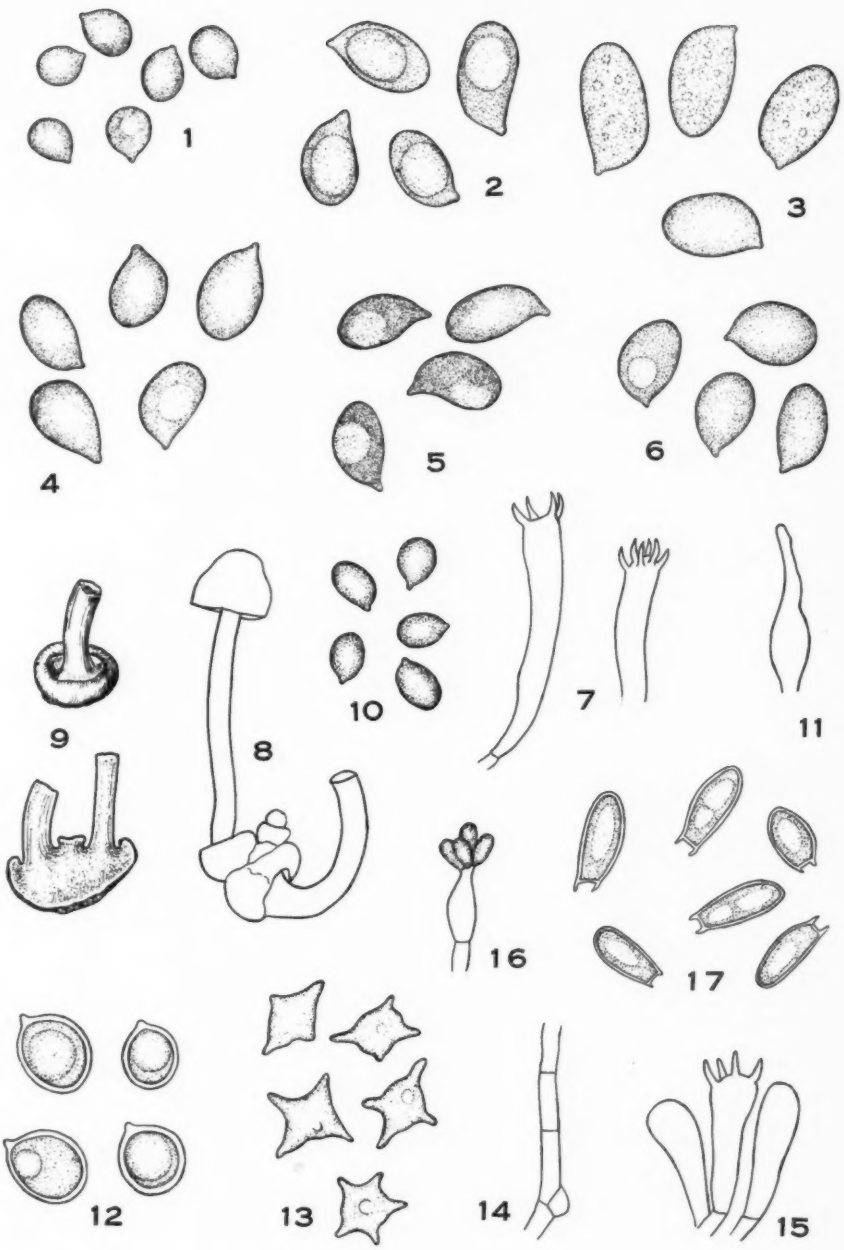
Boletus Ananas (top). No. 13756. Myrtle Beach, S. C. Photograph by Dr. Hugh Smith. × about ½.

Boletus sphaerosporus (bottom). No. 13994. St. Paul, Minnesota. Slightly reduced.

PLATE 24

Boletus placidus. Highlands, N. C. (Top) *in situ*; (bottom) No. 13289. Slightly reduced.

PLATE 25



BOOKS FROM CHAPEL HILL

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There are described under the genus *Boletus* sixty-eight species and six varieties. Of these, three species and four varieties are described as new. Four species of *Boletinus* and one of *Strobilomyces* are also included. Twenty species are illustrated in color and nearly all of the others by halftone photographs.

There are 96 pages of text; 6 colored plates; 55 halftone plates; and 5 plates of line drawings showing microscopic details. $7.00.

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